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SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Headquarters Office: 55 West 42d St., New York 36, N.Y. Telephone: LOngacre 5-0172

Executive Secretary: BOYCE NEMEC

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By DONALD G. FINK

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5. *Image continuity.* Here the factors are fusion of motion, flicker, frame or raster stability and color break-up.

This list is by no means exhaustive, but it includes the important areas in which technical advances can be expected to occur. Let us start, then, with the first category.

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The second factor in the viewing situation is the range of available viewing positions. Here the appropriate psychophysical common denominator for comparing the systems is the vertical viewing angle, that is, the angle subtended by the height of the screen at the viewer's eye. It is evident that so long as the height of the screen is chosen in proportion to the depth of the room or theater, the range of available viewing angles is the same in all the systems.

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Color television and color photography today occupy an anomalous relationship. As industries they are sharp competitors, but as techniques they are partners. The competition stems from the struggle of television broadcasting and the motion-picture industry to acquire public following at each other's expense. Since neither side has any prospect of a permanent monopoly of good actors, directors or writers, the leaders of the two industries are paying a great deal of attention to technical methods, in the hope that by exploiting their respective media to the utmost they may acquire a competitive advantage. The wide screen, the increasing use of color, and the substantial effort to improve color film and processing are evidence that Hollywood is taking its techniques almost as seriously as its talent. In fact, in many of the late lamented experiments in 3-D production, the factor talent was almost ignored.

The partnership between the two media lies, first, in the fact that television broadcasters use a great deal of film produced specially for network programs. This film must be adapted to the viewing conditions of the home, and its producers must reckon with the resolution, contrast and tonal gradation of the typical television image. A second activity of the partnership is film recording of video programs. This is a highly exacting art, the successful practice of which demands intimate knowledge of the two media.

Thus far, these efforts have been largely confined to monochrome productions. But it seems clear that the *ultimate* destiny of television and motion pictures is color, and we can probably take "ultimate" to mean not later than the end of the next decade. It seems appropriate, therefore, to examine the technical roots of the systems of color reproduction, and to locate the areas where expert attention is needed to sharpen the competition or to cement the partnership. For this paper, we have elected to compare three color systems: the NTSC-FCC compatible color-television system, the amateur color motion-picture system (8mm and 16mm film) and professional motion pictures (35mm film). The categories of comparison are:

1. *The viewing situation.* This includes the comfort and convenience of attending the performance, the choice of available positions with respect to the screen, the aspect ratio and the viewing angle presented by the screen and the effect of the surroundings.

2. *Image photometry.* This includes image brightness, contrast, tonal gradation and the errors of brightness transfer introduced by the system.

3. *Image colorimetry.* This includes the gamut of reproducible hues and saturations, transfer of chromaticity values, flat-field uniformity, reference-white considerations and errors of chromaticity transfer introduced by the system.

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Table I. Theater Viewing Conditions.

Name and location	Seating capacity	Vertical viewing angle, degrees Rear	Middle	Front	Screen dimensions, feet	Aspect ratio	Highlight brightness, ft-L
Arcadia Theater, Philadelphia	625	9	16	60	27×18	1.5	7
Commodore Theater, Philadelphia	1105	6	11	55	33×15 27×15	2.2* 1.8	7
Erlen Theater, Philadelphia	1500	10	17	63	55×22	2.5*	6
Fox Theater, Philadelphia	2422	11	18	70	52×22	2.4*	7
Green Hill Theater, Philadelphia	706	9	22	42	22.5×16	1.4†	5
HiWay Theater, Jenkintown	540	9.5	22	75	36×18	2.0*	15
Lane Theater, Philadelphia	1000	8	16	60	33×22	1.5	12
Logan Theater, Philadelphia	1862	9	17	70	40×18	2.2*	10
Mastbaum Theater, Philadelphia	4387	10	17	57	60×25	2.4*	7
Stanley Theater, Philadelphia	3000	12	18	45	38×22	1.7	6
Stanton Theater Philadelphia	1375	10	16	53	30×20	1.5	10
Viking Theater, Philadelphia	1012	10	19	50	46×18	2.5*	6
Yorktown Theater, Elkins Park, Pa.	875	9.5	17	60	32×18	1.8	10
AVERAGE VALUES		9.5	17.5	58		1.96	8.3

* For CinemaScope. † Foreign films.

The height of the image on the 21-in. color television tube now emerging as standard is about 14 in. An image of this size is customarily viewed from across the short dimension of the room, or from the center of the room if the receiver is placed against the narrow wall. The typical viewing distance is then about 8 ft (96 in.). The maximum viewing distance is set by the long dimension of the room, which is seldom greater than 240 in. The minimum distance, aside from those chosen by the very young, is about 48 in. The range of vertical viewing angles available with a 21-in. television set thus ranges from 3° upward to about 16° with a typical median value of 8°.

Home motion-picture screens, according to the latest issue of the Sears, Roebuck catalog, vary in height from 18 to 52 in. Since the whole area of the screen is not always occupied by the image, a better index of the viewing angle is the vertical projection angle of the projection lens. The most popular types are the 1-in. lens for 8mm film and the 2-in. lens for 16mm. The vertical projection angle of these lenses is, interestingly enough, equal to the typical television viewing angle, that is 8°. This means that the projectionist sits at a distance equal to 7 times the picture height. Other members of the family tend to line up on the optic axis of the system to get the maximum benefit of the directional properties of the screen. Unless the family group is large, the projectionist occupies the rear position. Accordingly, the range of vertical viewing angles is from about 8° upward. The minimum value of 3° encountered in television is rare in home motion pictures.

The range of viewing angles in theaters is not markedly different. A survey of 13 theaters in and near Philadelphia reveals the data listed in Table I. This shows that the minimum angle, in the rearmost seats, varies from 6 to 12°, with an average of 9.5°. The most popular seats, those chosen by the first patrons to enter the theater, are those just behind the center of the hall, from which the screen height subtends an angle of from 11 to 22°, an average of 17.5°. The maximum angle, from the front seats of the theaters surveyed, ranges from 42 to 75°, the latter figure corresponding to viewing a 21-in. television screen at a distance of less than 1 ft. Here again the minimum viewing angles tend to be larger than those used with a 21-in. television screen.

Since motion pictures employ larger viewing angles than television, it may well be argued that color television needs a larger screen than the 21-in. variety. The increasing popularity of the 24-in. screen in monochrome sets bears this out. The limit is reached when the cabinets fail to pass through standard-size doors. For this reason, progress toward larger color tubes must be accompanied by an increase in the deflection angle from its present maximum value of about 70° to 90°, as has occurred in monochrome practice. Once these techniques have been worked out, the size of color television images can be expected to increase moderately, to an upper limit set by the length of the average living room, perhaps to an image diagonal of 27 in. Work toward such a tube seems justified by the data just presented.

The third factor in the viewing situation is the ratio of the screen width to height (aspect ratio). Here professional motion pictures have recently proved that they are much more flexible than television and home motion pictures. The 4:3 aspect ratio of television was derived from the prewar standard for motion pictures. Now that there are 35,000,000 receivers in use, with picture tubes, mounts and cabinets geared to this ratio, there is a vanishingly small chance of changing it. Even if compatibility did not prevent such a change, there is some doubt that a wider screen would benefit television productions since the reduction in horizontal resolution might seriously degrade the image. A wide-screen system for 8mm home motion pictures is doubtful for the same reason.

A wide-screen system for home motion pictures is perhaps warranted with 16mm film and can be achieved without basic changes in equipment. Wide-screen images can be achieved by using wide-angle lenses in camera and projector, by cutting off the top and bottom of the image in the projector and by confining the objects of interest to the corresponding area in the camera viewfinder. This procedure reduces the resolution substantially below normal for the 16mm system but not below that of the 8mm system. In fact, if the twice-normal aspect ratio of CinemaScope is used, the result is two 8mm pictures side by side.

Motion-picture theaters are becoming increasingly committed to the wide screen. None of the 13 theaters surveyed had an aspect ratio smaller than 1.5 (except those exhibiting foreign films) and the average was 1.96. The projection of standard 1.33 ratio film on such wide screens leaves much to be desired and there are those who will argue that the wide screen is a temporary manifestation. Resolution is indeed a problem, but there appears to be sufficient reserve in the 35mm system to satisfy most of the customers most of the time in this respect. And there is little doubt that the wide screen offers a wider scope of action and hence the display produces a greater degree of realism in productions made especially for the larger aspect ratios. My guess is that some form of the wide screen for motion pictures is here to stay.

Here we have the first example of a major weapon on the side of professional as well as amateur motion pictures: flexibility in system standards. Producers and exhibitors have found it feasible to equip cameras and projectors with anamorphic optical attachments, at trifling cost compared with the costs of talent and theater operation in general. Stereoscopic presentations can also be arranged, although it is now abundantly clear that the customers will not cooperate by wearing cardboard spectacles. When a system requiring no such cooperation is invented, there will be no

fundamental bar to its introduction in theaters. Television in contrast has proved many times that, for reasons of compatibility, its standards are inviolate. They may be added to, as in compatible color, but they may not be changed.

The final item of comparison in the general viewing situation is the effect of ambient light and the screen surround. The control of ambient light in theaters has the advantage in that it makes possible presentations of high contrast, with a minimum of distraction from the surroundings. But, according to lighting experts, the ambient lighting in most theaters is too low in relation to the brightness of the screen (Table I). Higher levels of general illumination are needed not only to make it easier for patrons to move about but also to minimize the fatigue caused by too great a difference in brightness between the screen and its surround. When the surround brightness is not less than one tenth the average image brightness, eyestrain from this cause is avoided. The effect of the ambient on image contrast can be controlled by so arranging the lighting that it does not directly illuminate the screen but does brighten the surround to the desired degree.

In television viewing, high levels of ambient light are the rule in most household. To maintain contrast under these conditions, neutral density filters are used. In recent months, two such filters have become standard equipment in de luxe black-and-white receivers, one built into the tube faceplate (about 70% transmission) and the other in the safety glass (about 50% transmission). To maintain brightness when two such filters are introduced, the initial brightness of the phosphor image must be increased by a factor of 2.8. In exchange for this increase, the reflected ambient light is reduced to 12% of the value it would have in the absence of the filters, and the overall effect is a potential increase in contrast range of about eight times. With such an arrangement, the televiewer can be just as lazy as he likes about drawing the blinds or lowering the lights. He gets good solid blacks under any reasonable condition of ambient light. But this is possible only because the monochrome set designer has light to throw away.

In color-television receivers, image brightness is so costly that only one neutral filter is used; this is a 70% transmission faceplate. Control of ambient lighting is thus a more serious matter with a color receiver. Brighter images, by a factor of about three times, are needed before color sets can be said to be on a par in this respect with monochrome television practice.

Table II. Characteristics of Color Television and Motion-Picture Systems.

	Color television (Note 1)	8mm home motion pictures (Note 2)	16mm home motion pictures (Note 3)	35mm motion pictures (Note 4)
Vertical viewing angle:				
Minimum	3°	8°	8°	9°
Median	8°	15°	15°	17°
Maximum	16°	50°	50°	58°
Screen dimensions:	14 by 18.5 in.	13 by 17.5 in.	13 by 17.5 in.	16–25 by 23–60 ft
Aspect ratio:	1.33	1.33	1.33	1.4–2.5
Highlight brightness:	20 ft-L	15 ft-L	27 ft-L	5–15 ft-L
Contrast range:				
Large area	50-to-1	50-to-1	60-to-1	70-to-1
Small area	20-to-1	10-to-1	20-to-1	30-to-1
Resolution:				
Horizontal	280 lines	230 lines	490 lines	1000 lines
Vertical	350 lines	230 lines	490 lines	1000 lines
Product H × V	98,000	52,900	240,000	1,000,000

Notes:

1. Based on receiver employing 21-in. shadow-mask tube, 25-kv ultor voltage, 500 μamp peak beam current.
2. Based on 8mm home projector, 750-w lamp, $f/1.6$ 1-in. coated lens, 21-in. image diagonal, nondirectional screen, 3 projection periods/frame.
3. Based on 16mm home projector, 750-w lamp, $f/1.6$ 2-in. coated lens, 21-in. image diagonal, nondirectional screen, 4 projection periods/frame.
4. Based on data listed in Table I.

Photometric Properties

The next category includes the photometric properties of brightness, contrast and gradation. The brightness levels achieved in the three systems are shown in Table I which gives actual measurements of highlight brightness in the theaters surveyed, and in Table II which compares the performance of color television and color motion pictures.

It is customary to rate motion-picture projection brightness by measuring the screen with the projector running, but with no film in the gate. The SMPTE standard for theaters states that the screen brightness under these conditions shall be between 9 and 14 ft-L. The optical transmission of color film, in the clear portions corresponding to the highlights, is seldom higher than 60%. The corresponding highlight brightness levels in theaters are, therefore, 5 and 8 ft-L. The measured highlight levels in Table I fall in this range, although one of the smaller theaters reached 15 ft-L. Brightness above about 20 ft-L is undesirable, since flicker begins to appear at this level at the standard motion-picture projection rate.

Home projectors vary widely, according to the wattage of the projection lamp, the $f/$ number of the projection lens, the size of the image and the directive properties of the screen. To make the appropriate comparison with color television, measurements were made with two de luxe projectors having 750-w lamps and $f/1.6$ coated projection lenses, at an image size equal to that of the 21-in. television tube (diagonal 21 in.) projected on a flat-white nondirectional screen. The open-gate brightness of the 8mm machine was found to be 25 ft-L and the corresponding highlight brightness about 15 ft-L. The figures for the 16mm projector were 45 ft-L open-gate and 27 ft-L highlight brightness. The higher figures in the 16mm case reflect the greater opportunity for efficient design in the larger optical system.

Color television, as previously noted, is presently having trouble with highlight brightness. Depending on the second-anode voltage and peak beam current built into the receiver, the highlight brightness of a 21-in. image ranges from 15 to 20 ft-L. This matches the 8mm home projector, but falls short of the 16mm projector. It also falls short of the peak highlight brightness of a typical 21-in. monochrome set employing a 70% transmission, aluminized picture tube, which is typically 50 ft-L without excessive loss of focus. Unless and until color television receivers reach the 50-ft-L level, they cannot be said to meet the requirements imposed by the ambient lighting levels in the average living room. Meanwhile, those possessing color sets must take care to control room lighting.

Consider next the contrast range of color systems, that is, the ratio of the maximum brightness to the minimum brightness that can be present simultaneously in the reproduced image. The upper limit on contrast range in color motion pictures is imposed by the neutral density range of the film. According to Brewer, Ladd and Pinney,* a neutral density range of 3 is attainable in representative color films. Since density is the negative logarithm of transmission, this means that the film proper can provide a contrast range of 1000 to 1. The density range of the color image as presented on the screen is typically 1.85, that is, a contrast range of about 70 to 1. This substantial reduction in the contrast capability of motion pictures is traceable primarily to lens flare in the projector; it emphasizes the importance of keeping the projector lens clean. Ambient light on the screen would further reduce the contrast range.

* W. Lyle Brewer, John H. Ladd and J. E. Pinney, "Brightness modification proposals for televising film," *Proc. IRE, 42:* 174–191, Jan. 1954.

Measurements made by the writer in theaters and on home motion-picture screens show that a maximum contrast range between large areas of from 50-to-1 and 100-to-1 is attainable. The contrast between adjacent small areas is not so high, owing to halation and similar effects. At a resolution of 200 lines in the RETMA Resolution Chart, for example, the measured contrast in an image projected from 16mm reversal Kodachrome film in a typical home projector was found to be only 10-to-1.

The contrast attainable in color-television images today is somewhat lower than that of professional motion pictures. Ladd and his colleagues assign a luminous range equivalent to a neutral density of 1.3 to a color-television system employing a shadow-mask tube. This is a contrast range of 20-to-1. The measurements on which this value was based were made in early 1953, and a great deal has happened to color television in the meantime. In particular, higher peak brightnesses have been obtained, without corresponding increases in the shadow brightness, so the attainable contrast has risen appreciably since 1953. Recent measurements on a 21-in. shadow-mask tube show a large-area contrast of 50-to-1 and a small-area contrast of 20-to-1. In other work, large-area contrasts as high as 100-to-1 have been measured in the absence of ambient light.

It thus appears that color television and color photography are not widely dissimilar in their contrast properties, so far as the system apparatus is concerned. The difference lies rather in the degree to which the effects of ambient light are controlled. In motion pictures, the reflecting screen does not distinguish to any great degree between image and ambient, so that control of the ambient light is a prime necessity despite its high cost to the comfort and convenience of the viewer. In television, the image is transmitted rather than reflected to the viewer, so that discrimination against the ambient is possible to any desired degree, subject only to the amount of light the designer can afford to throw away in neutral filters. In the long run, therefore, it appears that color television has the advantage in that it can offer images of high contrast without special measures to darken the room. But, as we have already noted, this desirable state of affairs waits on the development of picture tubes having many times the highlight brightness presently attained.

The third item in image photometry is tonal gradation, that is, the distribution of brightness among the shades of gray in the image, relative to those in the original scene. This is tested by photographing or televising a step tablet, that is, an array of gray patches arranged in increasing steps of luminance. Here we encounter the fact that neither television nor photography can cover the range of brightness inherent in average outdoor scenes. Hence in reproducing such scenes, compression of the highlights or shadows is inevitable if the intermediate grays are reproduced in direct proportion to the original scene values.

Indoor scenes are more amenable to control. In motion-picture studio work, it is customary so to control the illumination that the most brightly lighted part of the set receives no more than four times the light falling on the most dimly lit part. In color-television studios, the illuminance ratio is held to about 2-to-1 wherever possible. These illuminance ratios, combined with the fact that a typical white object has about 20 times the reflectance of a black object, keep the scene contrast within about 80-to-1 in motion-picture work and 40-to-1 in television. Since these contrast ranges can in fact be reproduced on the viewing screen, under properly controlled viewing conditions, strictly proportional portrayal of the gray scale is practical and desirable. This implies an overall transfer gradient (gamma) of the system close to unity.

Some compression does in fact occur, in both color photography and color television, in the darkest parts of the image, with resulting loss of detail and texture in the shadows. But this effect is not prominent in the overall subjective evaluation of the image since shadow detail is commonly degraded in direct vision by the adaptive mechanism of the eye.

When the contrast range of the scene fits the contrast range of the reproducer, we have met only the first condition for correct rendition of tonal values. Another evident requirement is that the luminance of a particular portion of the image shall remain fixed when the luminance of the corresponding portion of the scene is fixed, regardless of what happens to the luminances of the other portions of the scene. In particular, the level of subjective black in the image should not shift to gray merely because an actress wearing a dark dress walks on the scene, nor should shadow detail in the image disappear altogether when the studio lighting is raised from a low value.

These degradations of tonal reproduction occur all too frequently in television. In motion pictures they do not occur because there is actually no mechanism in photography whereby the luminance of one object can be made to shift merely by a change in the luminance of another object. Speaking in electronic terms, it is the nature of the photographic beast to be direct coupled, from scene to negative, negative to print and print to viewing screen. In television, there is unfortunately a substantial opportunity for such luminance shifts to occur. Electrically, the error arises from an incorrect value of the d-c component of the video signal applied to the color television tube.

Most television cameras and all television transmission circuits are capacitively coupled, which means that the *average* ordinate of the signal remains *constant*, regardless of changes in the average illumination of the scene. Special measures must therefore be taken to insert and reinsert the correct average level. The burden first falls on the studio operator, who inserts the d-c component manually, by direct observation of the studio in relation to a monitor image. Necessary tolerances in the operation of studio equipment and in the ensuing transmission process over the network require that the system be permitted to err in this determination by as much as 10% of the maximum tonal range of the signal. The burden is taken up, secondly, in the d-c restoration circuits of the receiver. D-c restorer circuits of economical design (diode peak detectors) are not perfect in their action, even with a strong signal, and they fail badly when the noise level is high.

The net result of these impediments is that d-c restoration has been almost entirely abandoned in monochrome-television receivers. This means that the average brightness of the image is controlled *only* by the brightness control knob of the receiver, *not* by the average brightness of the scene. This seriously affects the tonal reproduction of the system as a whole, since every luminance tends to shift so as to keep the average brightness constant. For example, every fade to black at the studio comes out as a fade to an average gray on the receiver screen. Televiewers have learned to live with this sort of reproduction, but if they are critical of such matters, they know every motion-picture performance they ever saw was far ahead of television in this respect.

The situation is somewhat better in color-television receivers. Here, at least up to the time of writing, d-c restorer circuits are included since it is almost impossible to maintain white balance and correct colorimetry in a 3-gun tube without them. How long this advantage will be maintained rests with the future, particularly the future economy of the television manufacturing business. Because d-c restorer circuits cost money, they will very probably be removed from color sets just as soon as their removal can be shown to do no more harm to a color receiver than it does to a monochrome set.

Here again we have a technical advantage on the side of photography. Correct tonal gradation is available without extra cost in motion-picture systems, since it appears as a by-product of correct exposure and processing which are seldom more expensive than incorrect exposure and processing. In television, correct tonal gradation is not to be had without extra cost. Good d-c restoration performance adds perhaps ten dollars to

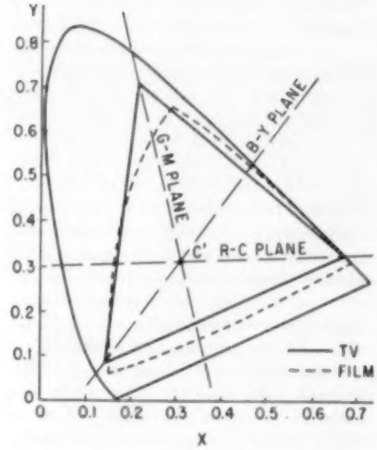

Fig. 1. CIE chromaticity diagram showing representative color gamuts covered by television and film (Courtesy W. Lyle Brewer, John H. Ladd and J. E. Pinney, "Brightness modification proposals for televising film," Proc. IRE, 42: 174–191, Jan. 1954).

the list price of a television receiver, and if the good performance of the circuit is maintained in fringe areas, another five or ten dollars may be added. So its future in color receivers is highly problematical. Once d-c restoration is removed from receivers, the studio operator will realize that he doesn't need to make a special effort to set black level accurate to within a few per cent because the customer cannot tell the difference. The advantage of color motion pictures over color television in tonal reproduction will become, at this stage, a permanent matter.

Colorimetric Properties

Turning now to the colorimetric properties of the color systems, let us consider first the gamut of hues and saturations that can be covered by the dyes used in color motion-picture projection prints compared with that of the phosphors used in color television picture tubes. Hues and saturations are shown conveniently on the CIE chromaticity diagram. Such a diagram appears in Fig. 1, taken from Brewer, Ladd and Pinney, where hues are measured by the angle around the white point C′ and saturation increases radially from that point. The solid-line triangle on this chart shows the gamut covered by the receiver primaries assumed as typical and attainable in the NTSC color signal specification. The broken-line figure bounds the corresponding gamut for a typical dye system used in motion-picture projection prints. The most important fact is that these two figures cover very nearly the same ground. Television can reach more highly saturated greens than can film, film slightly more saturated blues, reds and purples than television. But these are minor differences, especially since the eye is not critical of errors in saturation at these extremes.

Much more important is a difference which the color triangle in Fig. 1 hides, namely the limits on luminance that are imposed by the respective systems in the highly saturated colors. To show the luminance range, it is necessary to consider a 3-dimensional solid in color space, of which Fig. 1 is merely the top view. Three sections taken through this solid are shown in Fig. 2. At the left is a slice through the solid from magenta to green, shown from left to right, and with increasing luminance upward (corresponding to decreasing density upward); the middle slice is from cyan to red; the slice at the right from yellow to blue.

In each case we find that at high levels of luminance, below an equivalent density of about 0.5, the television system is capable of producing more highly saturated colors than is the motion-picture system. This is explained by the fact that each of the film dyes absorbs in regions outside that of its major absorption.

Here is a weapon in the hands of the television engineer. He can make more vivid (more highly saturated) bright colors than can his brother in the photographic art. To show this fact in another way, we can take a horizontal slice through the color solid at the 0.5 level of density, as shown in Fig. 3. Here the

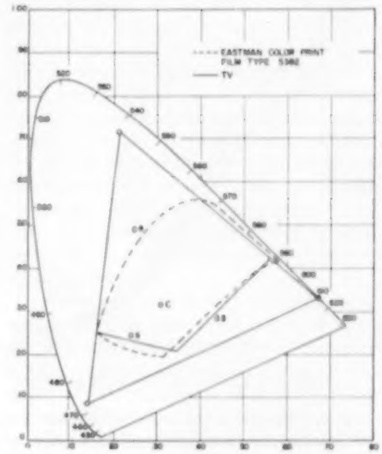

Fig. 3. Color gamuts bounded by a density of 0.5.

inner figures represent the performance of the photographic dyes, the triangle that of the television phosphors.

It must not be inferred from this that the television system has no trouble in reproducing highly saturated colors at high luminance. Such colors are transmitted by chrominance signals of high amplitude which may not be properly handled in the system. The signal for yellow at maximum luminance, for example, actually exceeds the amplitude range of the transmitter and must be clipped off, resulting in reproduction at lower saturation. Moreover, the demand on the transmitter for high-saturation, high-luminance colors varies widely according to the system of gamma correction adopted, and the gamma-correction standard is at the moment indefinite. Nor must it be inferred that the superior ability of color television to deal with highly saturated bright colors is an overwhelming advantage, since such colors are not prominent in nature and hence are seldom presented to the camera. But, in a side-by-side comparison, it is a fact that television has an advantage over motion pictures in the rendition of bright vivid colors, when use

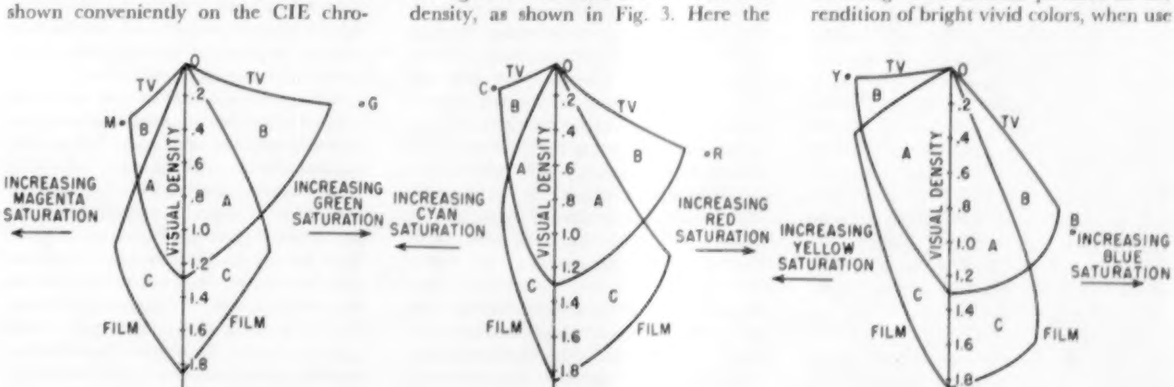

Fig. 2. Three sections of the color solid showing density and saturation. These correspond to the traces shown in Fig. 1.

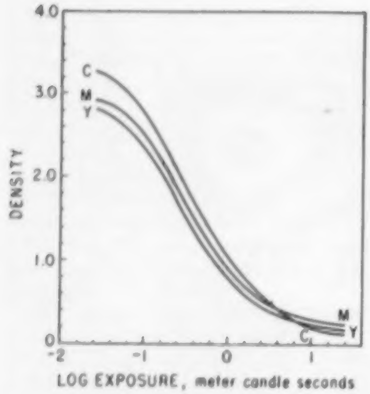

Fig. 4. Relationship between exposure and density in typical reversal color film processes.

is made of the full capabilities of the respective media.

Referring again to Fig. 2, it should be pointed out that the data shown indicate that the motion-picture system has a greater density (contrast) range than television and hence is capable of rendering a higher degree of saturation at low brightness than is the television system. Since recent improvements in the contrast performance of color television tubes have more nearly equalized the contrast range of the two media, the outlines in Fig. 2 are somewhat misleading. In any event, high saturation is of particular importance in the higher luminance ranges, much less so in the shadows. In consequence, the upper regions in Fig. 2 are the significant ones, and they indicate a definite superiority for color television when highly saturated, bright colors are to be reproduced.

The next item in colorimetry is the ability of the systems to reproduce the gray scale without introducing color tints at any of the luminance levels. White and gray are reproduced by mixing definite proportions of the reproduction primary colors, and this proportion must be maintained precisely, at all levels of luminance, if the reproduced gray scale is to be truly neutral in color. Stated differently, the transfer characteristic relating intensity of a primary color before the camera to intensity of the same primary on the receiver screen must have the same shape as that for the other two primaries. To reproduce a tintless gray scale, it is not necessary that the transfer curves be straight lines (gamma unity); but the three curves must have the same shape. (To reproduce a mixture color other than gray, the gamma of the system should be close to unity, in order to preserve the specific proportions of the primary colors at all levels of luminance.)

In this matter of primary-color transfer, the curves shown in Fig. 4 show the relationship between exposure and density in the cyan, magenta and yellow dyes in a typical reversal color film process. The three curves are closely similar in shape. One would expect, therefore, that the gray scale reproduced on such film would display a high degree of neutrality throughout the full range of luminance demanded of the system. This expectation is realized in 16mm Kodachrome shots of the RETMA Resolution Chart.

The color-television receivers now available to the public (as of early 1955) do not perform so well in this respect. The difficulty lies in the fact that the three electron guns of the shadow-mask color tube used in such receivers are operated in dissimilar fashion. The red phosphor is substantially less efficient than the green and blue phosphors, so the red gun is operated at its maximum current capability while the other two guns are backed off to produce the proper white balance. Under these conditions, it is very difficult to secure similarly shaped transfer characteristics for the three primaries. The grid biases of the guns are adjusted to obtain as good a match as possible, but in most color sets a shift in the color of the raster is clearly evident as the brightness control is rotated through its full range. This effect is difficult to avoid when a 3-gun tube is operated so as to attain maximum brightness. Eventually the quality of the televised gray scale will match that of the photographed gray scale, but further development is needed.

Another colorimetric requirement is uniformity of color over the area of the image, commonly referred to as "flat-field" uniformity. This may be tested in photography by exposing the film to a uniform white area and placing optical filters of various colors in succession in front of the lens. (During the oral delivery of this paper a 16mm Kodachrome film was projected to show flat color fields taken in this manner. There was very little evidence of color nonuniformity, either as a function of position over the image area or as a function of time.)

Color shifts with time are, in fact, often detectable during the running of color films in theaters. For example, flesh tone may change from pale to ruddy and back again within a few seconds as a result of minor variations in exposing, printing or processing the corresponding frames of the film. Usually such effects are hidden by the changes in illumination that accompany motion of the subject or camera. Those technicians who enjoy looking for the cue marks at the end of each reel may further amuse themselves looking for such color shifts, particularly between successive reels, during their next visit to the local motion-picture theater. A print that does not show them has been very well printed, even by modern standards.

Color nonuniformity is present to a considerably greater degree in the 3-gun color tube. One cause, which may be built permanently into the color tube, is localized lack of balance in the efficiency of the three sets of phosphor dots. Close inspection of a color tube, illuminated by a blank white raster, will show some of this effect in the form of slight color tints in certain areas of the screen which appear irrespective of other adjustments of the receiver components. Another cause is misadjustment of the color purity coils or magnets, which allows the electrons from one gun to stray onto the phosphor dots assigned to the other two guns. Malfunctioning of the circuits — for example, poor 15-kc response in one of the primary-signal video amplifiers — can produce the effect. Finally, localized unbalance in the photosensitivity of the three camera tubes used in the color camera can, and all too often does, contribute a major share of nonuniformity. Since there are so many possible sources of this difficulty in color television, we must assign the superior position in color uniformity to motion pictures.

Next, consider the reference-white question. The axiom in color studios is: Use film balanced for the white light used in the studio, take care with the flesh tones and trust your luck for the rest. The first step, balance for white, has led to the double inventory problem in vending color film to amateurs. One type of film is balanced for average daylight and is used out of doors; the other (Type A) is balanced for tungsten light and is intended for shots under artificial illumination. The color film enthusiast does not live who has never made a mistake in keeping his film and his illumination straight. Using the wrong film, or the wrong filter, with the illumination actually on hand is, in fact, one of the standard initiatory rites into the sacred precincts of the domestic color motion picture.

Here the amateur motion picture comes off second best, because the color balance has to be built into the film, and only two conditions can be accommodated in the commercial distribution system. Professional motion pictures are somewhat more flexible.

Color television has almost unlimited flexibility in this respect, since manual adjustments in the studio can balance the camera for a wide variety of studio illuminations, assuming proper gamma correction. Strangely enough, not until the NTSC was finished with its deliberations on the compatible color standard was it realized that *permission* to make such adjustments had not been written into the proposed standards. Such rigidity would have had the effect of forcing the broadcaster to use a daylight taking characteristic with tungsten light, which might have been just as disruptive

as taking Kodachrome Type A film off the market. The omission was forthwith corrected, and the final standard reads: "The radiated chrominance signal shall vanish on the reference white of the scene." This correction put the technical director of a color-television production back in business. The fact that the color-camera taking characteristics are capable of electrical control is a blessing, but not an unmixed one. The balance knobs are there; but it takes some fortitude to keep one's hands off them, once the white card has been held before the camera and the balance has been set.

Finally, in this discussion of colorimetry, consideration may be given to errors of chromaticity transfer introduced by the respective systems. Here it is difficult to make a precise comparative assessment, except to acknowledge that the motion-picture people have been worrying about this problem for twenty years longer than their television brethren and are therefore presumably in the lead.

Errors of chromaticity are shown by arrows in the CIE chromaticity diagram. One end of the arrow shows the hue and saturation presented to the camera, the other end the corresponding hue and saturation presented to the viewer. So long as these arrows are small compared with the dimensions of MacAdam's ellipses of least perceptible color difference, the system is above reproach from the scientific point of view. But in an artistic medium, such accurate rendition of hues and saturations is often positively undesirable. To create the illusion of reality, or to improve on reality, most producers and directors of professional color motion pictures strive for some sort of controlled distortion of chromaticity transfer. When one tries to assess the validity of the distortion, one quickly finds oneself in an argument with an artist, which is entirely unprofitable. Producers and directors of color television shows have the same problem and attack it in the same way, with the same disregard for Robert's Rules of Order.

The distinction between television and motion pictures is the degree of control available in the distortion of chromaticity. Here photography wins, at least for the time being. The manufacture of film and its processing are much more standardized than are the corresponding processes of signal generation and transmission in color television. For example, the vagaries of electronic gamma correction are real, honest vagaries at present. So the producer of motion pictures more often sees what he wants, in the color values displayed by release prints, than does the producer of color television on the monitor screen. Time will bring the two media closer in this most important matter of pleasing color rendition; but as of now the burden of rapid progress is definitely on the television engineer.

Image Structure

We come now to the differences among the systems in the structure of the images they provide. The first item is resolution, one of the few matters on which reasonably specific numerical comparisons can be made. We shall take as the basis of comparison the standard definition of television resolution, namely, the maximum number of adjacent black and white lines that can be discerned in a distance equal to the height of the image. (This is twice the number of lines as defined in optical measurements.)

Experience abundantly confirms that the resolution of black-and-white television is limited by the system standards to about 350 lines vertically, and to about 320 lines horizontally. In compatible color, assuming that registration of the primary images is not at fault, the corresponding figures are about 350 lines vertically and about 280 lines horizontally. The 12% degradation in horizontal resolution in the color system is imposed by the restricted bandwidth available for the luminance, necessary to accommodate the chrominance signal.

The resolution of a typical amateur home motion-picture system, using Kodachrome reversal film, has been measured by the writer in a manner strictly analogous to the television case by photographing the RETMA Resolution Chart, projecting the processed film and reading the resolution wedges on the resulting image. Care was taken with focus of camera and projector, and it is believed that the results fairly represent the capabilities of the home motion-picture systems. Results: the 16mm system has a resolution of about 490 lines, vertically and horizontally; the 8mm system about 230 lines. We thus find that the color system falls between the film systems, rather nearer the 8mm level than the 16mm. This finding will be subject to argument from many quarters; it is typical rather than definitive. But the writer feels that reading the wedges as one finds them is worth a pound of theory. If the numbers are correct, the directors of color television spectaculars can get much valuable (and sobering) practice by taking up 8mm color motion pictures as a hobby. (The final section of the 16mm film projected at the convention illustrated the resolution capabilities of the system.)

Professional motion pictures using 35mm film with the 4 : 3 aspect ratio are, on the same basis, capable of 1000-line resolution. There is some degradation when, as is usual, the release print is made by the imbibition (Technicolor) process owing to minor losses of resolution in registering the dye images. Further degradation occurs when the image is anamorphically expanded, as in the CinemaScope process, which lowers the horizontal resolution by a factor of approximately two. The VistaVision process of exposing (and, in large theaters, projecting) the 35mm film twice as fast as normal, and thus getting more than twice the area per frame, more than meets the resolution needs of the wide screen. It is perhaps pointless to pursue the matter beyond this point. Professional motion pictures win easily on resolution, compared with the other color systems. The only competition they have is that provided by other professional motion-picture systems.

Closely related to resolution is the rendition of texture. This is not merely the difference between rough and smooth. It includes such subtle distinctions as the sheen of metals, variations in the weave and surface treatment of textiles and impressions conveyed by small highlights. It appears that high resolution is not so important in reproducing texture as is high contrast range in small areas. A color display capable of reproducing the highlights on the eyeballs of an actor, for example, gives an impression of realism lacking when highlight compression is present. Similar contrast distinctions in the shadows are essential to depicting the texture of coarse woven surfaces. Both television and photography have sufficient contrast range for this, but tonal compression is more prominent in television. This fact, coupled with higher resolution, gives the superior position in reproduction of texture to professional motion pictures.

The sharpness of reproduced images is limited fundamentally by the heterogeneous nature of the fine structure of the image. In photography, assuming that no limit has been imposed by the optics of exposure, printing and projection, sharpness is limited by the graininess of the emulsions and dyes used. Photographic graininess is affected by the processing conditions as well as the density of the film. But graininess has at least the simplicity of being a quantity specifically associated with a given type of film stock and its processing.

The corresponding heterogeneous quantity in television, noise, is more involved. If noise were totally absent, the sharpness of television images would be limited by the scanning apertures of camera and picture tube, and by the amplitude and phase responses of the transmission system. Needless to say, television images are never entirely free of noise. For one thing, color cameras require from three to five times as much light as monochrome cameras for the same signal-to-noise ratio. This means that extra lighting has to be installed in converting a studio for color productions. Additional lighting sufficient to overcome camera noise under all conditions is hardly justified, even if it were possible. So close inspection of color monitor images usually shows camera noise at luminance levels below middle gray.

If this were the end of it, there would be little cause for complaint. But at every succeeding stage in the transmission process up to the transmitting antenna, designers of equipment have necessarily contented themselves with noise figures less than perfect. The RETMA standard for noise in transmission amplifiers and relay amplifiers is no help. Neither is the FCC standard on the same subject. Both standards, in fact, are entirely nonexistent. In general, it is considered good if when the picture signal leaves the transmitter, it has a video signal-to-noise ratio, peak white to root-mean-square noise, of better than 40 db (100-to-1 voltage ratio).

Possibly such noise performance is good enough, but its visible effect is substantially greater than that of the grain in the average Technicolor release print, so here again photography wins.

Progress in this line is particularly difficult for television engineers, because a large and increasing segment of the television audience lives more than 20 miles from the transmitter, and/or uses an indoor antenna, and/or is located in a natural or man-made canyon below line of sight—all of which conditions bring into prominence the noise introduced by the television receiver itself.

To serve this segment of the audience, designers of television tuners have been in quest of the lowest possible noise figure. In 1947 figures ranged from 15 to 25 db, but the vhf tuner of today hits better than 10 db, and 6 db is a good bogey figure. On some channels, some tuners actually go to 3 db, which is very, very good (such a tuner adds noise power to the signal passing through it to the extent of only two times the level of thermodynamical perfection). Uhf tuners are worse than the vhf variety, by 6 db in a good tuner, by more like 10 db in the average uhf tuner produced in the past two years.

The general introduction of good noise figures in receivers has meant that a very much larger portion of the audience gets reception uncontaminated by receiver noise, and a great many more square miles within which a recognizable image is receivable are added to the coverage of the station. The television industry is so conscious of this problem that continued effort can be confidently anticipated.

It must be admitted that the noise problem in television is fundamentally different from the grain problem in photography. The home motion-picture addict gets his grain given to him by experts; so does the theater exhibitor. But the owner of a television set finds a layman, himself, in the act. Ignorance of the causes and effects of noise in television reception is widespread. The engineers cannot force the owner in an outlying district to put up a better antenna, or to move in closer to town. Therefore, noisy pictures are all too common in the major part of the area claimed as served by the broadcasters. Fortunately, this part of the area is sparsely populated; the majority of televiewers can get pictures free of receiver noise as long as they confine their attention to local stations. This fact justifies a lot of work on camera and network noise. We in the United States can well afford to adopt the high standard set by the British Broadcasting Corp. in the matter of noise introduced prior to radiation of the signal.

The next topic under image structure is geometric distortion. In photography, the dimensions of the scene, as focused within the camera, are reproduced on the viewing screen in correct proportion unless very special means are taken to prevent it. It is possible to use lenses or shooting angles to distort perspective. But whatever are the shapes of things as the image lands on the negative, just so are the shapes as they fall on the viewing screen.

In television the situation is almost reversed. It is not too strong to state that the shapes of objects on the television viewing screen are not in correct proportion to those focused on the camera tube unless very special means have been employed to make them so. This trouble arises from the necessity of analyzing the image into the vertical and horizontal components of scanning. Unless the velocities of scanning in the receiver match the corresponding velocities in the camera geometric distortion occurs. Result: Circles appear as circles in film reproduction, but they all too often have the shape of an egg in television reproduction.

This problem has been recognized for a long time, and it must be acknowledged that the major stations and networks are taking a great deal more trouble with linearity of camera scanning than they did ten years ago. Friends in the network headquarters assure us that most camera-scanning systems have a positional linearity error under 2% (that is, the position of the picture elements never departs from the correct position by more than that amount, except accidentally and in emergencies).

Receivers do not fare so well. It appears, in fact, that horizontal scanning circuits as presently designed have positional linearity errors on the order of 4% (corresponding to scanning velocity errors of 10% or more). This is not to say that better linearity is not achieved in particular cases; it is to say that the 4% figure is accepted as a design objective. Nor is this designer's choice an arbitrary one. Careful study of the problem has shown that the means to improve horizontal linearity to the level of excellence now offered by the broadcasters are so expensive in components and power consumption that they are not justified in the highly price-competitive atmosphere of the television receiver industry.

These remarks apply to monochrome broadcasting and reception. In color television, since the camera has three camera tubes whose scanning systems must match each other with great precision, adjustments and operating procedures are available for a substantially improved grade of scanning linearity. Moreover, in studios where live color programs are produced, it appears that the standard is high in this respect. In color receivers of the type currently available to the public, however, there is no particular need for extra care in the scanning circuits, and the performance is not noticeably better than that of black-and-white receivers. The conclusions are: Photography inherently preserves the shapes of objects; television tends to distort them, and the burden of correcting this situation lies principally with the designer of the receiver scanning circuits.

Consider next the principal color error in the structure of the image, that is, misregistration of the primary colors. In monopack film, there is no chance for this error to occur, so the typical amateur color motion picture is distinguished by substantially perfect registration. Professional motion pictures taken by color separation negatives offer an opportunity for misregistration; so also do release prints made by the imbibition process. But the fact is that the registration problem in these processes has been taken in hand and solved by the designers and operators of the equipment. Prints having such errors simply are not released to the exhibitors, at least to judge by critical examination of the product now showing in theaters.

Registration errors do occur in color television, so much so that the writer has to date never seen a live color broadcast that was completely free of them. The problem at the studio lies in keeping the rasters of the three camera tubes precisely alike in width and horizontal centering, height and vertical centering, angular orientation, vertical linearity and horizontal linearity. Color film televised by the flying-spot method gets around this difficulty, since only one source of light, the scanning spot, is used. A similar correction-in-principle is needed to remove the problem in live cameras; what is needed is a single-gun color camera tube.

In receivers using the shadow-mask color tube, misregistration comes from another cause known as convergence errors. These may be simply described as excessive differences in the angles at which the three beams pass through a given aperture in the shadow mask, which arise from the fact that the three beams do not originate from the same point. Dynamic correction is used to bend the beams so that at the edges of the picture they appear to have originated from the same sources as at the center of the image. As the maximum deflection

angle has increased from 50° in the early tubes to about 70° in the latest version, the problem has become worse, and more sophisticated convergence correction methods have become necessary.

When in good adjustment, the convergence correction system keeps misregistration down to a small amount, say about $\frac{1}{32}$ in. in a 21-in. tube. But exact registration, all over the face of the tube, appears to be practically unattainable, as anyone who has wrestled with convergence correction while observing a dot pattern can testify. Misregistration of this amount is readily tolerated when viewing a color image from the normal distance, but it does detract from the overall excellence of the image when black-and-white programs are viewed on the color tube. What is needed to correct the situation is a color tube free, in principle, of convergence errors. Conclusion: On excellence of registration, score one for photography.

The final comment on the relative structure of the color images relates to the simultaneous utilization of the whole area of the motion-picture frame, compared with the sequential nature of television scanning. Since the television image is composed of two sets of lines laid down alternately, two minor defects of image structure are present: virtual pairing of interlace and jagged edges of vertical boundaries. These are visible on close inspection, even if the scanning system is otherwise faultless, whenever the eye moves in following the motion of the image or as any other motion of the head occurs. For example, the difference between scanning and area-type displays is never more evident than when the viewer is eating peanuts. This pastime has little effect on the appearance of a motion-picture image; but the chewing motion moves the head sufficiently to cause the television image to appear to move about, in localized bumps and grinds. If you have never noticed this, try it at the next opportunity. Peanut brittle is an appropriate confection for the purpose.

Image Continuity

We come to the last of our categories, the differences in the apparent continuity of motion and illumination inherent in the frame repetition rates of the three systems. Home motion pictures are exposed at 16 frames/sec., professional motion pictures at 24/sec. and color television at 30/sec. As these numbers suggest, television outperforms the color motion-picture systems, particularly the home motion-picture system, when it comes to fusion of motion. Actually television has a further advantage in that each frame is divided into two fields, which are separately exposed and reproduced, and the motion in the image is thus cut up into 60 segments/sec. Professional motion pictures have only 24 such segments; the shutter action in the projector (which projects each frame twice) is helpful only in removing flicker, not in smoothing out fast motion.

The camera operator in television thus has substantially less stringent limitations in the speed with which he can pan the camera, compared with the motion-picture cameraman. The wide screen adds to the problem because there is correspondingly more ground to be covered in the horizontal direction. In fact, it is my observation that the outstanding technical shortcoming of wide-screen motion-pictures is the jerkiness of motion apparent when an actor moves across the full width of the screen at an above-normal pace. In the older "narrow-screen" productions, panning of the camera would have been used to transfer the jerkiness from actor to background. This camera technique is apparently not popular in wide-screen productions.

Continuity of illumination, that is, control of flicker, is also heavily stacked on the side of television by its high repetition rate. Here the appropriate numbers are 60 fields/sec for television, 48 screen illuminations/sec for professional motion pictures. Since the threshold of flicker is a logarithmic function of brightness, the permissible screen illuminations in the two systems are widely different, typically 180 ft-L for television and 20 ft-L for professional motion pictures. In home projectors, the screen is illuminated three times per frame (typical of 8mm projectors) or four times per frame (used in some 16mm machines), making flicker rates of 48 and 64/sec, respectively, when the film is run at the standard rate of 16 frames/sec. The home projector thus approximates or exceeds professional motion pictures in flicker performance.

These brightness limits of television and motion pictures are closely related to the viewing conditions discussed at the beginning of this paper. Screen brightness less than 20 ft-L is the rule in motion pictures, not only because it is difficult to make large images brighter than this, even with the most powerful light sources, but also because of the flicker problem. Television can handle any image brightness likely to be demanded indoors, without fear of flicker.

Both television and the motion pictures have passed the day when the stability of the frame as a whole was a serious problem. Worn sprocket holes and misadjusted claws are, of course, always a potential source of jitter. Optical misalignment can cause weave in the immobilizer type of projectors used in flying-spot scanners. But ordinary care of film and alignment suffices to produce completely steady projection, even on amateur equipment. In television, raster stability is a function of horizontal and vertical synchronization circuits. These have been so improved during recent years that the raster remains steady even when the signal is so weak that the picture can barely be discerned against the noise. Critical friends who view motion pictures regularly say that film jitter is by no means totally absent and state that television is superior in this respect. Accepting this judgment, we give the edge to television in the matter of frame stability.

The final item under image continuity is color break-up, that is, the appearance of separately colored images when an object is in rapid motion. This effect cannot appear when all three primary images are present simultaneously in camera and image reproducer. So color break-up is no problem in color motion pictures or the simultaneous form of color television cameras, nor is it in televising color film. It can appear when a sequential type of camera is used, such as that used in the Chromacoder type of live pickup chain. But in that case, the color field rate is so high (about 180 fields/sec) that color break-up is visible only when the motion is very rapid, and even then it is likely to be noticed only by those keeping a sharp eye out for it. So we can cross out color break-up as a factor in the present-day systems of photography and television.

Summary

This completes the list of comparisons. A summary has been attempted in Table III. Each of the several areas of comparison mentioned in this paper is listed at the left and the superior system identified.

Study of this table reveals that color motion pictures come off best in most of the technical items, as might well be expected. After all, we are comparing color motion-picture systems which have enjoyed twenty-five years of steady development with a color-television system having less than five years of comparable technical activity. Very few of the distinctions (of which only one, resolution, is a major factor) are fundamentally rooted in system standards. Perhaps the most significant differences arise from the facts that the 35mm motion-picture system is under professional control from start to finish, and that price competition is not a large factor in the design of its equipment.

Two conclusions are unmistakable: First, television engineers have a long way to go to produce a color system that works as well as color motion pictures, and the task is not made easier by the requirement that the receiver perform well in the home where lighting conditions are not under control, and where the knobs are set by laymen. Second, omitting only the resolution limit imposed by the width of the television channel, there is no technical reason why the television engineer cannot meet the competition. In many cases, the needed improvements can be found without hav-

Table III. Summary of Color System Characteristics.

Characteristic	Superior System	Remarks
Viewing situation:		
Choice of viewing position	Television	On basis of viewer comfort and convenience
Viewing angle	Film	At median viewing position
Aspect ratio, flexibility of	Film, 35mm	Wide-screen professional motion pictures
Ambient light and surround	Television	
Image photometry:		
Highlight brightness	Television	
Contrast	Television	In presence of high ambient light
Tonal gradation	Film	
Errors of tonal transfer	Film	
Image colorimetry:		
Gamut of hues and saturations	Television	Particularly at high luminance
Gray scale, neutrality of	Film	
Flat-field uniformity	Film	
Reference white, control of	Television	As applied to camera
Chromaticity transfer distortion	Film	
Image structure:		
Resolution	Film, 16mm & 35mm	
Noise, graininess	Film, 35mm	
Geometric distortion	Film	
Misregistration of primary colors	Film	
Systematic structure errors	Film	Due to sequential nature of scanning
Texture	Film	
Image continuity:		
Fusion of motion	Television	
Flicker	Television	
Frame (raster) stability	Television	All systems highly satisfactory
Color fusion	Film	Not a significant factor

ing to surmount economic barriers. In other cases, the toughest engineering job of all must be faced: finding a better technique at no increase in cost.

We may then terminate the discussion with a question: What are the chances that the needed improvements in color television will be recognized, the needed support for research and development provided and the results put into production? The answer involves, I think, two distinct periods in the years ahead. Initially, the performance of color television receivers may actually be degraded, in certain respects which are acceptable to the buying public, in the process of reaching a price sufficiently low to permit every American family who really wants a color set to own one.

Following this, the television industry will be faced with the situation that has faced the automobile industry in recent months: a highly saturated market with buyers looking for something better, in looks and performance, than they now have. Then, it is to be devoutly hoped, the television industry will respond as the automobile industry has responded, with a steady upgrading of performance, accompanied, if necessary, by a corresponding upgrading of price. In this second phase of development, it is certain that those items of performance in a color receiver that are important to the customer, whether or not they enjoy a similar reputation among engineers, will receive concentrated attention.

During the same period, the motion-picture industry will not be standing still. Enjoying freedom in system standards, this industry will continue its forays into territory not likely to be invaded by a television system bound by the confines of compatibility. Two results seem certain: (1) engineers and physicists who understand color will enjoy steady employment, and (2) the public will enjoy the show.

Acknowledgments

The author acknowledges with gratitude the assistance of the following persons who read the manuscript and offered suggestions: A. G. Jensen, W. T. Wintringham and M. W. Baldwin, Jr., of the Bell Telephone Laboratories; R. E. Shelby of NBC; R. S. O'Brien of CBS; F. J. Bingley, W. P. Boothroyd, R. G. Clapp, J. F. Fisher and J. B. Williams of the Philco Corp.; and W. Lyle Brewer of the Eastman Kodak Co.; and of the managers of the Commodore, Erlen, Fox, Green Hill, Logan, Mastbaum and Viking theaters in Philadelphia for the data in Table I. Thanks are also due to Messrs. Brewer, Ladd and Pinney for the data of Fig. 3 and for permission to reproduce the figures credited to them and their associates in the test.

Supplement

The 16-mm motion-picture film shown with the reading of this paper at the Convention was produced on 16mm Kodachrome Type A using a Cine Special Camera, Model 1. The following notes serve to amplify the preceding text.

Text reference, page 286:

Eastman Kodak reflection gray scale with lens aperture varied from maximum (f/1.9) to minimum (f/16).

Text reference, page 286:

White paper photographed through the following color filters:

1. Exposed for white at 1200 ft-L, 8 frames, at f/5.6.
2. K-2 yellow filter, 8 frames, f/4.
3. Wratten F-29 red, 8 frames, f/2.7.
4. Wratten N-61 green, 8 frames, f/2.7
5. Wratten C-4 blue, 8 frames, f/2.7.
6. Through filter for photoflood (light blue), 8 frames, f/5.6.
7. Filter for outdoor exposure with Type A Kodachrome, 8 frames, f/5.6.

Text reference, page 287:

RETMA Resolution Chart at four levels of exposure. The following are readings of horizontal and vertical resolution: high exposure, 400 lines discernible, 350 lines with good contrast; medium high exposure, 500 lines discernible, 450 lines with good contrast; medium low exposure, 550 lines discernible, 500 lines with good contrast; low exposure, 600 lines discernible, 550 lines with good contrast.

FIRST INSTALLMENT

History of Sound Motion Pictures

By EDWARD W. KELLOGG

Excellent accounts of the history of the development of sound motion pictures have been published in this Journal by Theisen[5] in 1941 and by Sponable[6] in 1947. The present paper restates some of the information given in those papers, supplementing it with some hitherto unpublished material, and discusses some of the important advances after 1930.

One of the numerous omissions of topics which undeniably deserve discussion at length, is that, except for some early work, no attempt is made to cover developments abroad. The subject of 16mm developments is discussed with a brevity altogether out-of-keeping with its importance. This has been on the theory that basically the problems are similar to those of 35mm sound, and that whatever has brought improvement to one has been applied to both.

Edison invented the motion pictures as a supplement to his phonograph, in the belief that sound plus a moving picture would provide better entertainment than sound alone. But in a short time the movies proved to be good enough entertainment without sound. It has been said that although the motion picture and the phonograph were intended to be partners, they grew up separately. And it might be added that the motion picture held the phonograph in such low esteem that for years it would not speak. Throughout the long history of efforts to add sound, the success of the silent movie was the great obstacle to commercialization of talking pictures.

Early Sound Pictures Using the Phonograph

The idea of combining recorded sound with the motion pictures is as old as the motion picture itself[35] (if we exclude the early "zoetrope" invented in 1833 by W. G. Horner).[39] In a paper, "What Happened in the Beginning," F. H. Richardson[7] reproduced a letter in which Thomas A. Edison quoted from his early notes: "In the year 1887, the idea occurred to me that it would be possible to devise an instrument which should do for the eye what the phonograph does for the ear, and that by a combination of the two all motion and sound could be recorded and reproduced simultaneously." The letter proceeds to tell of the development of the motion picture (and is followed by letters from Thomas Armat, George Eastman, C. Francis Jenkins and others, related to motion-picture inventions). Edison in 1895 tried on the public the combination of a phonograph with his "peep show" moving picture.[5,11] He built at least 50 (and probably more) of the combination machines.

Gaumont. Leon Gaumont, in France,[5] began as early as 1901 to work on combining the phonograph and motion picture. He worked on the project during several widely separated intervals. Theisen[5] refers to a series of shows of the "Film Parlant" at the Gaumont Palace in Paris in 1913 and to demonstrations in the United States. After 1926 the "Etablissements Gaumont" used the system developed by Peterson and Poulsen.

Laemmle. An attempt by Carl Laemmle of Paramount in 1907 to exploit a combination of phonograph and motion picture is mentioned in Sponable's paper.[6] This was a German development called "Synchroscope." It was handicapped by the short time which the record would play, and after some apparently successful demonstrations, was dropped for want of a supply of pictures with sound to maintain programs in the theaters where it was tried.[13]

Pomerede, Amet, Bristol. Theisen's paper[5] mentions combinations of phonograph and motion pictures using flexible shafts or other mechanical connections, by Georges Pomerede[2] (1907 patent), and E. H. Amet[14] (1912 to 1918) who used electrical methods for the sound. Wm. H. Bristol[15] began his work on synchronous sound about 1917.

Siren Type of Amplifier. An ingenious attempt to obtain amplification in reproduction used the movements of the phonograph needle to vary the opening of an air-valve, connected to a source of air pressure. This device was employed for sound pictures by Oskar Messter[5,16] (Germany 1903–4). In England, where it was known as the "Auxetophone," it had some use for phonographs. Its invention is credited by the Encyclopedia Britannica to Short (1898), with improvements by the Hon. C. A. Parsons.

Edison. In 1913 Edison made a serious effort to provide synchronized phonograph sound. The equipment is on exhibit at the Edison Museum in West Orange, N.J. The phonograph is of special construction, to provide maximum volume and long playing, the cylinder record was oversize, and the horn and diaphragm considerably larger than those of home phonographs. Between the reproducing stylus and the diaphragm was a mechanical power amplifier, apparently using the principle of capstans used on shipboard. There was a continuously rotating amber cylinder and a hard rubber brake-shoe subtending about 130° of arc. One end of the shoe was connected to the reproducing stylus in such a manner that an upward displacement of the stylus would increase the pressure between shoe and cylinder; and the other end of the shoe was connected through a slender rod to the diaphragm, in such a way that the shoe movement resulting from increased friction would give an upward push on the diaphragm.[17] One may well imagine that the adjustment of this device to give substantial gain without producing chattering must have tested the skill of the best of operators. Nevertheless, it must have worked, for the record indicates that the Edison talking-picture show ran for several months in Keith's Colonial Theatre in New York, with much acclaim, and was shown in other large cities of America and in other countries.

The arrangement for synchronizing was not in accordance with present practices. The phonograph behind the screen determined the speed, being connected through a string belt to a synchronizing device at the projector. The belt pulleys were about 3 in. in diameter. The belt passed from the phonograph up over idler pulleys and overhead, back to the booth. The synchronizing device applied a brake to the projector, and the brake-shoe pressure depended on the relative phase of phonograph and projector, increasing rapidly as the projector got ahead in phase. With an even force

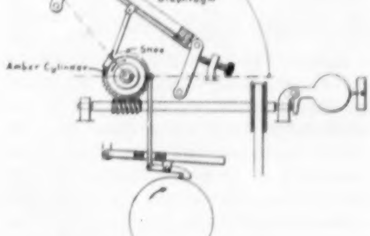

Fig. 1. Mechanical power amplifier of Thomas A. Edison and Daniel Higham.

Presented on May 5, 1954, at the Society's Convention at Washington, D.C., by Edward W. Kellogg, Consulting Engineer, 276 Merion Ave., Haddonfield, N.J.
(This paper was received on October 25, 1954.)

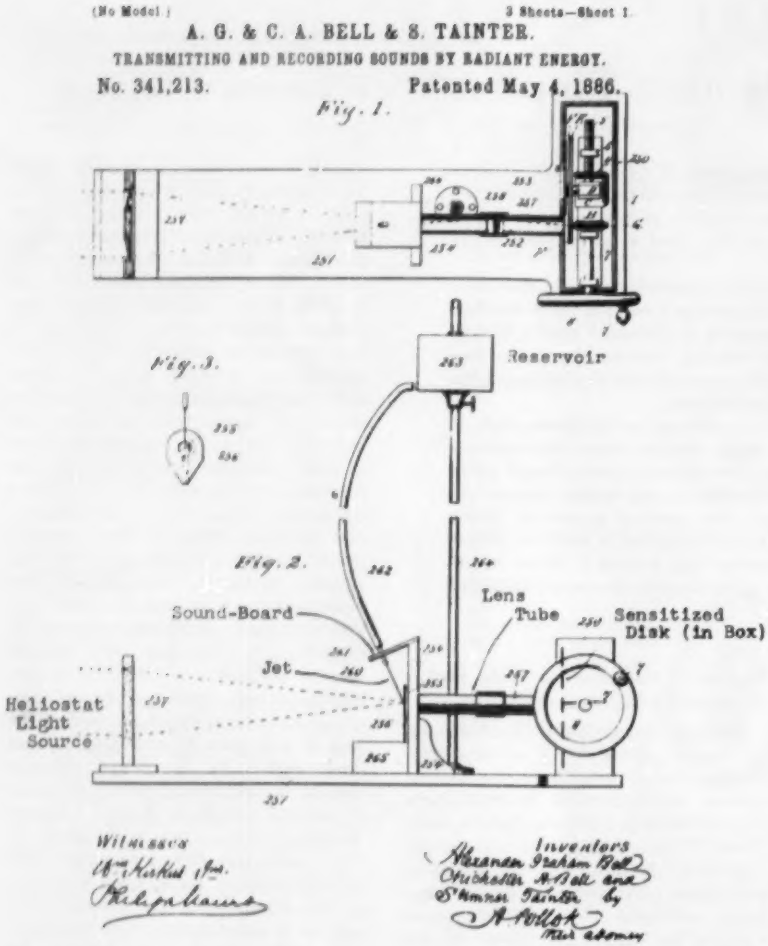

Fig. 2. Variable density recording system of A. G. Bell, C. A. Bell and Sumner Tainter, 1886.

on the projector crank, normal phase relation was maintained. The projectionist watched for synchronism and had a slight degree of control by turning the crank harder if the picture was behind or easing it off if it was ahead.

So far as I have learned, there were few further efforts (at least in the U.S.) to provide sound for pictures by means of phonograph (mechanical) recording until the Warner Brothers' Vitaphone system of 1926.

Photographic Sound Recording

A history of sound pictures necessarily includes the many efforts to record sound photographically, whether or not the experimenters made any attempt to combine the sound with pictures, or were even interested in that application. Despite the obvious advantages, from the synchronized-sound standpoint, of a photographic record of the sound on the same film with the picture, it does not appear that this consideration was necessarily an important factor in directing experimentation toward photographic recording, nor even that ultimate application to synchronous sound for motion pictures was (in many cases) a main objective. It was rather that photographic recording represented a new medium, which seemed to offer promise of much superior results. A mechanical system seems inherently crude where such delicacy is needed as in reproducing sound; in contrast to which recording by a beam of light would seem ideal. The experimenters have all been conscious of the handicap imposed by the necessity of making ponderable mechanical parts vibrate at high frequency.

So we find that efforts to record sound photographically began before there were such things as motion pictures on strips of film. Before the invention of the telephone, Alexander Graham Bell, interested in aiding the deaf, had made photographic records of "manometric flames," showing voice waves. His patent, No. 235,199, filed in 1880, shows a system for transmitting speech over a beam of modulated light, and uses a light-sensitive device (selenium cells) to detect the received fluctuations, thus anticipating the essential principle of the reproducing system which was used in many later experiments.

Blake. Prof. E. W. Blake of Brown University in 1878 made photographic records of speech sounds on a moving photographic plate, using a vibrating mirror.[6,18]

Fritts. U.S. Patent No. 1,203,190, filed in 1880 by Charles E. Fritts,[5,6] discloses photographic soundtracks and a great variety of devices for recording and reproducing, but there does not appear to be evidence of much significant experimental work.

Bell and Tainter. In the Smithsonian Museum in Washington, D.C., are a number of large glass disks carrying spiral sound tracks. These were made by a method described in U.S. Patent No. 341,213 (filed 1885) to Alexander Graham Bell, Chichester A. Bell and Sumner Tainter. Light from a steady source was transmitted in a relatively narrow beam through a piece of stationary glass, and then further restricted by a slit where it reached the circular photographic plate. Just above the place where the light entered the stationary glass, a tiny jet of ink (or other light-absorbing liquid) was directed against the surface. The nozzle was attached to a "sounding board" (small plate) which picked up the sound vibrations. The jiggles of the nozzle caused waves in the stream of ink which flowed down over the surface, and these modulated the transmitted light.

Some years ago it became desirable, in connection with a patent suit, to demonstrate that the spiral track was really a soundtrack. Contact prints (on celluloid films) were made of several of the most promising looking of the glass plates, and a reproducing system arranged, giving the record the benefit of modern equipment in this respect. The approximate best speed was found by trial. (The original recording machine was hand-cranked). The photographic image had suffered from age and was very noisy, and the total recording lasted only a few seconds. But it was with something of the thrill of an antiquarian that we listened to the voice from the past. "This is . . . . I am . . . in the . . . laboratory." The date was given too " . . . , eighteen eight- . . .?"

Others. Sponable's historical paper mentions numerous other workers and their patents. Several of these modulated the light by means of a small mirror connected to a diaphragm so that vibration caused rotation, thus anticipating features of equipment used by C. A. Hoxie in the work at General Electric Co. Of the developments which, although

not leading to any commercial system, deserve special mention, I shall speak of several inventions or discoveries which laid foundations for later developments, and of the direct contributions to photographic recording of Rühmer, Lauste, de Forest, Reis and Tykociner.

Basic Inventions and Discoveries

Selenium Cells. For many years, reproduction from photographic-sound records was made possible by the selenium cell. The photoconductive properties of selenium were discovered by Willoughby Smith in 1873, and a practical selenium cell was made by Werner Siemens in 1876.[19] The response of a selenium cell to changes in illumination is sluggish, making it a very imperfect tool for sound reproduction, whereas the photoemissive effect on which photocells depend is practically instantaneous, but the electrical output from a selenium cell is very much greater.

The Photocell. The first indication of photoemission was discovered by Hertz in 1887 and later studied by Hallwachs (1888), Stoletow (1890) and Elster and Geitel (1889 to 1913).[19,20] Although by 1900 much had been learned, practical photocells did not become generally available till some years later, nor were they of help toward sound reproduction without electronic amplifiers.[21,22]

Thermal Emission — The "Edison Effect." Edison discovered in 1883 that a small current could flow through evacuated space in a lamp bulb, between a hot filament and a separate electrode. The Fleming "Valve," invented in 1905, made use of this principle, played an important part in early wireless telegraphy and was the forerunner of thermionic amplifiers.[26]

The Audion. The invention of the "Audion" by Lee de Forest in 1907 marked the beginning of the electronic era. As has been emphasized by many writers, it was the electronic amplifier which unlocked the door to progress and improvement in almost every phase of sound transmission, recording and reproduction. However, amplifying tubes did not become generally available to experimenters for over a decade. The de Forest patent[23] (acquired by the Telephone Company) was basic and unchallenged, but the vacuum techniques of some of the foremost laboratories of the country[24] were needed to make of the audion a dependable and reasonably rugged tool.*

The Oscillograph. The oscillograph, consisting of a small mirror mounted on a pair of conductors, close together, in a strong magnetic field, was invented by Blondel in 1891 and improved in 1893 by Duddell, who put it into practically the form still used. It has played a vital part in photographic sound recording.

Magnetic Recording. The invention by Poulsen of Copenhagen in 1900 of recording magnetically on a steel wire laid the foundation for modern tape recording, which has almost revolutionized methods of making original recordings.[27]

Auditorium Acoustics. The modern science of room acoustics and acoustic treatment dates from the work of Prof. Wallace C. Sabine of Harvard in the years 1895 to 1900.[28] With little other equipment than a whistle, a stop watch and brains, he worked out the acoustic principles on which successful sound recording and reproduction so largely depend.

Gas-Filled Incandescent Lamps. Beyond a certain point, optical-recording systems cannot give increased exposure by increasing the size of the source, but only by increasing the intensity (candles per square centimeter), which means higher temperature. Early incandescent lamps were well exhausted because all gas results in loss of heat by convection and hence lowered efficiency. In 1911–13 Irving Langmuir of General Electric Co. studied the effects of inert gas not only on heat loss, but also on the rate of evaporation of tungsten from the filament surface, which is the factor which determines permissible operating temperature. He showed that such gases as nitrogen, or better yet argon (the heavier the better), at pressures well up toward atmospheric or even higher, could with suitably formed filaments so retard the evaporation of tungsten that the higher permissible temperature much more than compensated for the added heat convection, thus giving several-fold increase in efficency as well as whiter light. With the gas, the evaporated tungsten is carried to the top of the bulb instead of blackening the sides, in the optical path.[29]

Magnetic Materials. The development of several alloys of iron, nickel and cobalt having extraordinary magnetic properties is reported by H. D. Arnold and G. W. Elmen in the *Bell System Technical Journal* of July 1923, and by Elmen in the January 1929 and July 1929 issues. The extremely high permeability and low hysteresis of Permalloy have made it possible to greatly reduce distortion in transformers and in many electromechanical devices, and to provide more successful magnetic shielding than would otherwise be possible. In another alloy which has been called Perminvar, constancy of permeability and low hysteresis (making for low distortion) have been carried still farther. Another alloy named Permendur can carry very high flux densities before saturation, making it possible to produce intense fields which make for sensitivity and damping in devices of the moving conductor type.

Important for the reduction of cost and weight of magnetic devices was the discovery by the Japanese physicist T. Mishima of the properties of certain aluminum-nickel-cobalt alloys for permanent magnets,[30] and subsequent improvements.

Improvements in Vacuum Tubes and Phototubes. In any list of the advances which contributed in an important way to the technical attainments in modern sound reproduction, several improvements in amplifier tubes deserve an important place. Among these are:

(1) The Wehneldt (oxide coated) cathode and other low-temperature emitters, which in turn made indirectly heated unipotential cathodes possible.

(2) The screen-grid tube.

(3) The pentode.

(4) Remote cutoff or exponential tubes, and other variable gain tubes.

(5) The caesium phototube with its high sensitivity to infrared light.

(6) The gas-filled phototube with its increased output.

Early Work on Sound on Motion-Picture Film

Rühmer. Ernst Rühmer in Berlin[5,6,31] in 1901 began publication of the results of his work on photographic sound recording, which extended over a period of about twelve years. As sources of modulated light he superimposed voice currents on the continuous currents in electric arcs. He used considerably higher film speeds than those used for pictures. Sponable reported (ref. 6, p. 278) that some of Rühmer's Photographophon films were brought to this country by the Fox Film Corp., and that the articulation was clear; also, this reference shows a sample of Rühmer's soundtrack. A variable-area track by Rühmer is shown in the Theisen history (ref. 5, p. 421), the *Scientific American* of 1901[31] being cited as reference. Presumably Rühmer experimented with both systems.

Lauste. This Society has taken special note of the work of Eugene Augustine Lauste, in a 1931 report of the Historical Committee,[32] in a paper by Merritt Crawford[33] and in placing his name on the Society's Honor Roll. The young Frenchman joined the staff of Thomas A. Edison in 1887, where he did construction and experimental work till 1892. For two years he worked on another project and then, in association with Maj. Latham, developed a projector which was the first to incorporate the extra sprocket and free loops with the intermittent. Lauste's interest in photographic sound recording was first aroused when in 1888 he found in an old copy of the *Scientific American* (May 21,

* Much higher vacuum than de Forest had been able to obtain was necessary. This was independently accomplished by I. Langmuir of General Electric Co. and H. D. Arnold of Western Electric Co.[24]

1881) an account of Dr. Bell's experiment in transmitting sound over a modulated light-beam, and converting to electrical modulation by means of a selenium cell. This suggested the thought of recording the sound photographically on the same strip with the picture. It was not till about 1900 that he began to find opportunity to work on this project. He worked for several years in the United States and then went to England where he pursued his experiments. A British patent (No. 18,057, filed in 1906) shows a well thought-out system. Lauste received some financial backing in 1908 from the manager of the London Cinematograph Co.

To modulate the recording light, Lauste used rocking mirrors and what have been described as "grate-type light-valves." The mirror system was too sensitive to camera vibrations, and the grate-type valves which he was able to build had too much inertia. In 1910 he began working with modulators of the string galvanometer type, with excellent results. The historical account by Theisen,[5] shows photographs of some of Lauste's apparatus. He spent some time with Ernst Rühmer in Berlin, a stimulating and profitable association. He visited America in 1911 and as part of his demonstration made what was probably the first actual sound-on-film motion picture made in the U.S. A necessary return to England, shortage of capital, and the war, halted Lauste's sound-picture researches. In his paper on Lauste, Crawford expresses the thought that had it not been for this unfortunate interruption, plus very limited resources, and had electronic amplifiers been available to Lauste, commercialization of sound pictures might well have gotten started a decade before it actually did.

E. E. Ries filed application in 1913 for a patent (No. 1,473,976, issued in 1923) in which broad claims were allowed on the essentials of a single-film system. The patent became the basis of later litigation.[6]

Tykociner. In 1918 and following, Prof. J. T. Tykociner of the University of Illinois carried on experiments and developed a system. This work was described before the American Institute of Electrical Engineers and in the *SMPE Transactions*.[34] After pointing out that three new tools had in comparatively recent times become available for the solution of the sound-picture problem, (namely, high-frequency currents, photoelectricity, and thermionic amplifiers), Prof. Tykociner gives a broad discussion of requirements and possible arrangements. As a source of modulated light he used for the most part a mercury arc with either modulated continuous current or modulated high-frequency current, and for reproduction a Kunz (cathode of potassium on silver) photocell. The light from the mercury arc is particularly potent photographically, but is sluggish in following the input modulation, which results in some loss of the higher audio frequencies.

Foreign Developments Which Led to Commercial Systems

Tri-Ergon (meaning "the work of three"). Josef Engl, Joseph Massole and Hans Vogt, in Germany, began in 1918 the development of a system of sound pictures which later was commercialized under the name Tonbild Syndicat AG (abbreviated to Tobis).[6,35] They used a modulated glow discharge for recording, and a photocell for reproducing. Of chief concern in this country were the Tri-Ergon patents,[35] in which numerous claims allowed by the U.S. Patent Office were so broad that had their validity been sustained they would have almost swamped the industry. In particular, one patent (1,713,726) which claimed the use of a flywheel on the shaft of a roller or sprocket which carries the film past the translation point, to take out speed variations, was the basis of prolonged litigation, being finally declared invalid by the U.S. Supreme Court (1935).[114] But in the meantime the efforts to avoid what were thought to be dangerous infringements of the Tri-Ergon flywheel claims, had for seven years steered the course of mechanical designs on the part of the major equipment manufacturers into inferior or more complicated constructions. (See section on Mechanical Systems.)

In Germany the Tri-Ergon patents controlled the situation. The large picture producing companies, U.F.A. and Klangfilm (a subsidiary of Siemens & Halske and A.E.G.), took licenses under the Tri-Ergon patents. A brief account of the patent negotiations and agreements in this company and in Germany will be found in the Sponable paper.[6]

Peterson and Poulsen in Denmark developed a system (1923) which was commercialized in Germany under the name Tonfilm.[6] They used an oscillograph as the recording light modulator (giving a variable-area soundtrack), and a selenium cell for reproduction. (One of the Tri-Ergon U.S. patents[35] claimed the use of a photocell for this purpose, and it is likely that a German patent accounts for the use of a selenium cell by Poulsen and Peterson.) This system was used by Gaumont in France and by British Acoustic Films, Ltd.

The de Forest Phonofilm

Dr. de Forest tells the story of this work in the 1923 *Transactions*.[36] The account is particularly interesting because he tells much of his viewpoint as he started, and then, after describing the system which he had evolved, gives his reflections on the applications and future of sound motion pictures.

The man whose invention gave us amplifiers in which the heaviest object that had to be moved was an electron, surely had a right to wish to do away with moving mechanical parts in microphones, light-modulators and loudspeakers. For microphones he experimented with the conductivity of gas flames and of open arcs as affected by sound waves, and with fine platinum wires heated to a dull red by a direct current and subjected to the cooling effect of the air vibrations superimposed on a slight continuous air movement. The changes in resistance of the wires with variations of temperature gave rise to telephonic currents.

For light modulators he tried "the speaking flame" (probably the "manometric" flame of König) and a tiny incandescent lamp, carrying voice currents superimposed on direct current. The lamp was designed to have very rapid filament cooling (partly by using a short filament, so that heat conduction to the lead-in wires would be high). On listening to these sources by means of a photocell and amplifier, de Forest was convinced that they gave exceptional quality (even compared with the condenser microphone), but they proved entirely inadequate for making a useful soundtrack giving very small percentage of modulation and probably also underexposure. Finally a successful source of modulated light for recording was found in a gas-filled tube excited by modulated high-frequency currents from a 5- to 10-w radio telephone transmitter. This was named the "Photion." A slit, $1\frac{1}{2}$ to 2 mils wide and 3/32 in. long, adjacent to the film, was used to restrict the size of the exposing beam.

A similar slit was used in reproduction. Both potassium photocells and Case Thalofide[37,40] cells were used in reproducing equipment, the greater sensitivity obtainable with the Thalofide cell being a consideration offsetting the faster response of the photocell. The design and construction of amplifiers using his Audion were of course very familiar to de Forest.

Lament is expressed that loudspeakers depending on some principles other than diaphragms and horns were not to be had, but after some discouragements with "talking arcs" and sound radiators on the thermophone principle, the commercially available horn and diaphragm speakers were accepted as the only solution at the time.*

Practical models of recording and reproducing equipment were built, and re-

* It is of interest that in the early part of our investigation which led to the direct radiator dynamic speaker (*Trans. AIEE*, 1925, p. 461) Chester W. Rice and I tried talking arcs and thermophones, and also a corona discharge device — all of which avoid mechanical moving parts — but none of these appeared promising.[38]

cordings made, using principally a combined camera and recorder, and many demonstrations given.

The de Forest paper[36] reviewed earlier history of efforts to record sound photographically, and gave appreciative acknowledgment of the help that had been given by Theodore W. Case.[37]

To have guessed wrong on some subject is no reflection on the insight of an experimenter, but several instances are striking, in the light of later developments. Speaking of the efforts to provide sound by means of the phonograph, the author said: "The fundamental difficulties involved in this method were so basic that it should have been evident from their inception, that commercial success could hardly be achieved in that direction." (Consider the Warners' Vitaphone.) Speaking of loudspeakers, after saying that the loudspeaker has been developed "to a high state of perfection" but left much to be desired, he said: "I am convinced that final perfection will come not through any refinements of the telephone and diaphragm, but by application of entirely different principles." (Yet phenomenal improvements were made with the identical elements, through refinements.)

In speaking of the future of sound pictures, Dr. de Forest gave a definite "No" to the question whether the existing type of silent drama could be improved by the addition of voice. But he foresaw the evolution of an entirely new type of dramatic scheme and presentation, taking advantage of the freedom which had been such an asset to the silent moving picture (as contrasted with the stage) but using sound and voice where these could be effective. He also had visions of great utility for travel films, newsreels, records of notable persons, and educational films.

The work just described was done from 1918 to 1922. About a year and a half later[36] Dr. de Forest gave a brief account of progress, reporting improvements in many details, better articulation, thirty theaters equipped, much interest on the part of operators, films made of a number of celebrities and contracts with leading chain exhibitors. Again the opinion was expressed that the talking picture would not ever take the place of the silent drama.

The Phonofilm system was used in numerous theaters, with sound films made under Dr. de Forest's direction; but he did not succeed in interesting the established American picture producers. Perhaps the industry was prospering too well at the time, but judging from the initial coolness of film executives to the technically greatly improved systems a few years later, it is easy to imagine that numerous imperfections which undoubtedly existed (as, for example, defective film-motion, limited frequency range, and loudspeakers that gave unnatural voices, and perhaps too, demonstration films that were uninteresting) contributed to loss of the impressiveness needed for doing business.

Several years later the "de Forest Phonofilm Co." was bought by Schlesinger of London and South Africa.

Work at the Theodore W. Case Laboratory (Movietone)[6]

Theodore W. Case[37] became interested in modulating light and deriving telephonic currents from it in 1911, while a student at Yale. In 1914 he organized his laboratory at Auburn, N.Y., devoting special attention to the study of materials whose resistance is altered by light, of which selenium was the best known example. These studies resulted (1917) in the development of the Thalofide cell, in which the photosensitive material is thallium oxysulfide.[40] These cells, which are especially sensitive in the near infrared range, were widely used in Navy communication systems during World War I. Case was joined in 1916 by E. I. Sponable. Experiments were continued with the help of an Audion amplifier obtained from de Forest. One of Case's postwar developments was the barium photoelectric cell.

In 1922 attention was turned seriously to sound pictures. Manometric* flames (oxyacetylene) were tried as a possible source of modulated light. Soon afterward Case found that the light from an argon arc in one of the tubes that had been used for infrared signalling could be readily modulated and was photographically potent. These tubes had oxide-coated hot cathodes. A tube for recording, based on this principle, was developed and named the Aeo-light.[6,41] It operated at between 200 and 400 v. Helium was substituted for argon in 1922, with benefit to the actinic power and also to the speed with which the light followed the current variation. The commercial Aeo-lights were rated at 350 v.

From 1922 to 1925 Case cooperated with de Forest, furnishing numerous items of experimental equipment.

Several sound cameras were built under the direction of Sponable, in 1922, 1923 and 1924. The 1924 model was a modified Bell & Howell camera rebuilt to Sponable's specifications by the Bell & Howell Co. The film motion in this and other cameras was unacceptable until they had been reworked for greater mechanical precision. In the final designs of sound camera the sprocket was driven through a mechanical filter, consisting of damped springs and a flywheel on the sprocket shaft. The sound was recorded on the sprocket. The Aeo-light was mounted in a tube which entered the camera at the back. Directly against the film was a light-restricting slit made by silvering a thin quartz plate, ruling a slit 0.0006 in. wide in the silver, and cementing over it a thin piece of glass which was then lapped to a thickness of about 0.001 in. The slit was thus protected from collecting dirt from the film. The end of the Aeo-light, where the glow was concentrated, was close behind the slit. A Bell & Howell contact printer was modified to make possible the independent printing of picture and sound.

Up to the fall of 1925, when the working arrangement with de Forest was terminated, the Case laboratory efforts were directed largely to recording principles and apparatus. It was decided then to work on a system independently of de Forest, and one of the next projects was to build reproducing equipment in the form of an attachment which could be used with existing picture projectors. It was in this design that the decision was reached to place the soundhead under the projector, and the offset of 20 frames or $14\frac{1}{2}$ in. between picture and sound was established. The speed of 90 ft/min was adopted for the Case system. In the first projector attachment a light-restricting slit was used similar to the one used in the camera, but later a straight tungsten filament was imaged on the film, and in a still later model, a concentrated straight-axis helical filament was imaged on a slit which was in turn imaged on the film.

With the essential elements of a sound-on-film system developed, Case and Sponable began study of the patent situation, with a view to obtaining licenses, if necessary, for the commercial use of their system. There appeared to be no very strong patents to interfere, except those on the use of thermionic amplifiers. A contract between General Electric, Westinghouse and Radio-Corporation on the one hand and Western Electric Co. on the other, was in effect, specifying the fields of activity in which each might use amplifiers, but, if I have not misinterpreted the account in Sponable's historical paper, sound-pictures had not been specifically mentioned, and there was some question as to the right to license use in the Case system, the eventual decision being that both groups had rights. The Bell Telephone Laboratories were interested themselves in developing sound pictures, and so were not immediately ready to license what would be a competing system. However their engineers were much interested in the performance attained, and there was some thought of combining efforts. There were demonstrations of both systems, but no plan to merge them was reached. The experience of Case and Sponable at

* A gas jet so arranged that sound vibrations produce changes in the gas supplied to the jet.

General Electric Co. was rather similar.

In 1926 demonstrations were made to representatives of the Fox Film Corp., who became greatly interested, and finally to William Fox. After thorough testing on their own premises, the Fox Film Corp. purchased rights to the Case developments (July 23, 1926), leaving the question of amplifier rights to be worked out later. The Fox-Case Corp. was organized to exploit the system, which was given the name Movietone. Courtland Smith, who had been with the Fox Film Corp. and had been instrumental in bringing about the purchase, was made president of the Fox-Case Corp. The Movietone News service was established.

Sponable left the Case organization to give his services to the new company, one of the first of his activities being the design of recording studios in New York and later in Hollywood. In 1927 he developed a screen which transmitted sound freely, permitting loudspeakers to be located directly behind the picture. The first public showing of Movietone recordings was in January 1927.

The Fox-Case Corp. obtained license to use amplifiers, first in 1926 through the Western Electric Co. and the Vitaphone Corp., and the next year revised contracts were made with Electrical Research Products, Inc. (ERPI), which was formed in January 1927 to handle the sound-picture business for the Western Electric and Telephone companies.

In the Movietone reproducing system, Western Electric amplifiers and loudspeakers were used. The years 1928 and 1929 were marked by rapid expansion in facilities and personnel, successful showings and stepped-up schedules of newsreel releases. In March 1929 the making of silent pictures by Fox was discontinued. Six months later the Fox and Hearst newsreel services were united.

The British Movietone News was organized in 1929. In 1930 William Fox sold his interests in Fox Film and Fox Theatres.

As the Fox Film Corp. was already an ERPI licensee, and therefore had rights to use other Western Electric developments, the Western Electric light valve was adopted for the Movietone service (as well as for Fox studio recording), displacing the Aeo-light.

Work at Western Electric Co. and Bell Telephone Laboratories

The Western Electric Co. brought to a commercial stage almost simultaneously a sound motion-picture system based on disk records, and one based on sound on film. Various developments which laid the foundations for these systems had been taking place through a number of years. The citation of the life and work of Edward B. Craft in this *Journal*[42] indicates that his interest and enthusiasm were in large measure responsible for the undertaking of a full-scale project for developing systems of sound for motion pictures. Craft was assistant chief engineer of the Western Electric Co. from 1918 to 1922, when he became chief engineer. With the transfer in 1924 of research activities to the newly organized Bell Telephone Laboratories, Craft was made executive vice-president, and continued to guide activities.[43]

Whether or not there was a definite policy of not putting all of the eggs in one basket, work on both systems was stepped up at about the same time (1922) and pushed with equal vigor.

The two systems had identical requirements with respect to many elements, but, in particular, microphones, amplifiers and loudspeakers. The Western Electric Co. had acquired rights to de Forest's Audion in 1913 and made great improvements in it during the next few years, building up wide experience in its applications and circuitry.

Second only to electronic amplifiers in importance for the development of high-quality recording and reproducing systems was a microphone of uniform response and with low distortion. With amplifiers available Dr. E. C. Wente[43] was able largely to ignore the question of output level, and to develop by 1916 a microphone of the condenser type, having extraordinarily high fidelity and freedom from distortion and noise.[44–47]

In the loudspeaker field, the company had had considerable experience and had developed units for public address work. The public address installations had afforded experience with auditoriums and requirements for intelligibility, while experience in acoustics for sound pickup had been gained in radio broadcasting.

With respect to the recording itself and reproduction, I shall separate the two stories of the disk and photographic systems.

The Disk System

In 1946 there was published a history of sound recording in the laboratories of the Western Electric Co.[48] Since the transmission of speech was the main business of the Telephone Co., a program of studying every aspect of speech waves was initiated about 1912, and as part of this project, efforts were directed to recording the sound. The interest soon spread to include music. In connection with work with disk records, Crandall and Kranz built an electromagnetic reproducer in 1913. In 1915 H. D. Arnold suggested that the improvement of disk recording be undertaken, using the then available electrical equipment (which included amplifiers). By this time the electrical reproducer had been improved.

The war interrupted these projects, but they were resumed soon after its close. A group under J. P. Maxfield undertook the improvement of wax recording and the phonograph. The story of this development was told in 1926 to the American Institute of Electrical Engineers.[49] The recording system made use of a magnetically driven cutter so designed that with constant current input, the vibratory velocity of the cutting stylus was substantially constant from about 200 to 5000 cycles, while from 50 to 200 cycles the amplitude was constant, a characteristic practically necessary to avoid overcutting by the low notes. Two features of the design were of special interest: (1) the separation of the total mass that must be driven into three parts (armature, stylus-bar and coupling disk), connected together through portions of shaft whose torsional flexibility was carefully calculated to make of the structure a mechanical low-pass filter of calculable mechanical impedance; and (2) a mechanical resistance consisting of a thick-walled rubber tube (which may be thought of as practically a rod of soft rubber) subjected at one end through the coupling disk to torsional vibrations. The propagation of torsional waves in such a soft rubber rod is so slow that in a length of about 6 in. there would be many wavelengths for all but the lowest frequencies.

Vibrations imparted to the rubber reach the far end very much attenuated, are reflected, and propagated back toward the start, but are of neligible magnitude when they reach it. Under such conditions the rubber line acts as a nearly pure mechanical resistance to load the filter, and, if properly matched to the filter impedance, results in practically complete (and therefore uniform) transmission through the filter structure, throughout the frequency band below the filter cutoff. The features just described are, I believe, the inventions of H. C. Harrison. The great improvement in records which electrical recording brought, is well known to all of us.

Without a better reproducing system than the phonographs of the types in use about 1920, the improvements in the records would have been largely lost, so there was developed a greatly improved (nonelectrical) phonograph called the Orthophonic (also largely the outcome of H. C. Harrison's approach to the problem). However this part of the program had no direct bearing on the talking-picture project. In early 1925 the Columbia and Victor Companies took licenses from Western Electric Co. to use the recording methods and apparatus, and to build phonographs of the Orthophonic type.

Sound-on-Disk Synchronized With Pictures. Little time was lost in trying and demonstrating synchronized sound and pictures using the new electrically recorded disks. Craft arranged for a demonstration at Yale University in 1922 and another in February 1924, the equipment and many details of the system having

been developed and improved in the interval.

To provide sound for pictures, using the disk-record system,[50] it was necessary to have records which would play continuously for at least the projection time of a 1000-ft reel (about 11 min), to plan a synchronous drive, and to use electrical reproduction in order that, with the help of amplifiers, adequate sound output could be had.

It was not desirable (in view of background noise) with record materials then available, materially to reduce amplitudes of cuts, and so groove pitch had to be kept nearly the same as then in current use (about 100 grooves per inch). To maintain quality the minimum linear groove velocity must not be reduced. With a given groove pitch and minimum velocity, the maximum playing time for a given record diameter is obtained by recording to half the maximum diameter, and the required playing time determines the needed size and corresponding rotation speed. While the engineers could take some leeway, the choice of 16 in. outside diameter and $33\frac{1}{3}$ rpm, approximately met the conditions indicated.

For synchronous recording, the camera and the recording turntable can be driven by selsyn motors, which driving system gives the equivalent of both being geared together and driven from one shaft. Starting marks on both film and disk are of course essential.

For reproducing, the turntable and projector were mechanically geared together. A simple magnetic pickup, if not damped, has a high-frequency resonance in which the armature whips, giving excessive output and high mechanical impedance at the needle tip.[51] The magnetic pickup used in the sound-picture system was designed for use with replaceable steel needles and damped by enclosing the moving elements (except the needle-holder and needle) in oil.[50]

The turntable driving systems[50-54] evolved for the sound pictures are discussed in the section on "Mechanical Systems" — the great problem being (as had been the case throughout the history of sound recording) to obtain sufficiently nearly constant speed.

The loudspeakers which had been developed for public address applications[55] were of the "balanced armature" type, had good power-handling capacity, and were regarded as fairly satisfactory from the standpoint of articulation. Designs of horns had been evolved which fairly successfully controlled the directivity for auditorium purposes. In 1923 Dr. Wente built a speaker of the moving-coil type which gave greatly improved quality[56] (especially the better bass response which is possible with the moving-coil drive), but in terms of efficiency and power-handling capacity it was not satisfactory. It was not until 1926 that a speaker of the moving-coil type was developed by Wente and Thuras[57] which met the requirements for quality, efficiency and power-handling capabilities. Speakers of this design rapidly superseded those of earlier design, and continued in use for years.

According to the account of Lovette and Watkins[45] the sound-on-film system, on which another group of engineers had been engaged, was capable in 1924 of matching the quality of the disk system, but the latter represented an older art in which there were fewer uncertainties. The greater confidence with which the company could offer the disk system, and with which a potential customer would consider it, were responsible for choosing it as the first to be pushed. However, interest on the part of most of the picture producers was cool, nor did Craft, conscious of the numerous failures of previous efforts by others, think it desirable to hasten the commercialization of either system until its weaknesses were worked out.

Samuel Warner and Vitaphone.[58] With many details omitted, the foregoing is the description of the sound-on-disk system which became known as Vitaphone. Col. Nathan Levinson,[40] then serving the Western Electric Co. in the Pacific district where he had had close association with Samuel L. Warner, made a business trip to New York early in 1925 and saw a demonstration of the sound pictures. He felt sure that Mr. Warner would be interested, and arranged for a demonstration at the first opportunity. Samuel Warner was more than convinced, and his enthusiasm quickly spread to his brothers. More thorough tests were arranged, using cameramen, technicians and artists of the Warner staff, in cooperation with Western Electric engineers. The adoption of sound by a large picture-producing company would mean a huge outlay, and its success was a question not only of technical performance, but of the artistic, dramatic and psychological results which could be achieved through the addition of sound. The tests were convincing to the Warner Brothers, if not to the executives of some other picture companies who witnessed them. To develop and market sound motion pictures and equipment, the Vitaphone Corporation was organized in April 1926, with Samuel L. Warner as its president.

The first major Vitaphone sound picture to be released was *Don Juan*,[1,48] (August 1926) in which music by the New York Philharmonic Orchestra was featured. The new loudspeaker developed by Wente and Thuras was ready in time for this. Preparations were made for producing sound pictures in Hollywood, where sound stages were erected embodying the recommendations of the foremost experts in acoustics. The production of *The Jazz Singer* with Al Jolson, was begun in the spring of 1927 and it was shown in New York on October 6. Its success was such that the industry was convinced "overnight" that the day of sound pictures had arrived.

Improvements in the Disk System. Under the title "Recent Advances in Wax Recording"[59] H. A. Frederick tells of a number of advances subsequent to the 1926 account by Maxfield and Harrison. By improvements in record material and wax processing techniques, it had been possible to reduce surface noise by 3 to 6 db. A new pickup (4A) is described with smoother response and good to about 4500 cycles, as compared with 4000 cycles for the previous model. A response curve for the commercial recorder shows practically uniform response to 5500 cycles. Laboratory models of recorder and reproducer are mentioned as carrying the response to 7500 cycles. The new recorder used a longer rubber damping line. Frederick gives the groove pitch as 10 mils and the minimum groove velocity as 70 ft/min. He also reported very satisfactory results with re-recording.

Western Electric Sound on Film

Mention has been made of fundamental studies of speech waves, begun in 1912 and carried on through several years until interrupted by the war. Amplifier tubes became available as laboratory tools in 1913. Photographic records of speech waveshapes were made, using at first a carbon transmitter, an amplifier and a Duddell oscillograph. The weakest link in this chain of equipment was the transmitter, whose response varied greatly with frequency and which had a high level of background noise, making it difficult to get reliable traces of consonants and other relatively weak speech sounds. The development of a better transmitter was one of the first undertakings of Edward C. Wente,[43] who came to the company in 1914.[44-47]

The Condenser Transmitter. If the charge on a pair of condenser plates is maintained through a sufficiently high resistance, the voltage is directly proportional to the separation of the plates, so that a transmitter based on this principle is an amplitude-sensitive device. If the diaphragm, which is one of the condenser plates, is so stiff in relation to its mass that resonance occurs above the required frequency range, the diaphragm deflection is proportional to the instantaneous air pressure. Wente met this mechanical requirement by using a stretched steel diaphragm 0.002 in. thick and spaced 0.001 in. from a relatively massive backplate. The very thin layer of air contributes greatly to the stiffness of the diaphragm, but the flow of air through the narrow space toward and from a relief space around the edges causes damping, so

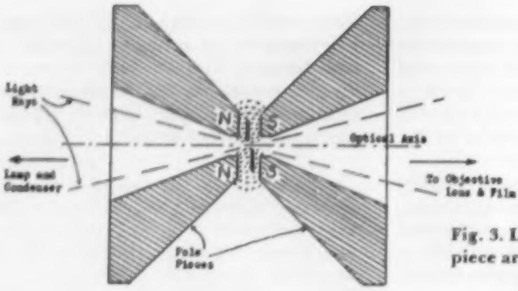

Fig. 3. Light-valve ribbon and pole piece arrangement; section at right angles to ribbons.

that a nearly flat (uniform) response was obtained up to about 15,000 cycles.

Wente left the company in 1916 for graduate study and returned in 1918. In the meantime Dr. I. B. Crandall had made a theoretical analysis of the air-film damping, and improved the instrument by means of grooves of appropriate size and shape in the backplate.[45] For measurement purposes it was essential to calibrate the condenser transmitter, and Wente accomplished this by working out the theory of the thermophone, which enabled him to make a reliable pressure calibration.[46] Free field calibrations were made later, using a Rayleigh disk as reference. In a later design,[47] which was used commercially for sound recording, the sensitivity was greatly increased, in part by use of aluminum alloy 0.001 in. thick instead of 0.002 in. steel for the diaphragm, and in part by not carrying the response as far into the high-frequency range. (In 1931 W. C. Jones published a pressure calibration curve for a #394 transmitter which showed a rapid drop above about 7000 cycles.[47]) The condenser transmitter is rated as a a very insensitive device, but it is of interest that a diaphragm deflection of a millionth of an inch will give a fifth of a volt, the gradient in the space between electrodes being 200 v per mil. It is the extreme stiffness of the diaphragm which makes the sensitivity low.

Photographic Recordings. The condenser transmitter with amplifier gave better waveshape traces, but the narrow mirror of the bifilar (or Duddell) oscillograph causes diffraction effects which make the light-spot at the film blurred or fuzzy. Prof. A. C. Hardy showed[60] that this trouble could be largely eliminated by radical changes in the optical system in which the oscillograph vibrator is used, but his analysis was not published until 1927 (in time to be of much help in the General Electric recording developments, but the Western Electric experiments with the oscillograph were before 1920).

An article in a British Journal (1920) came to Wente's attention, describing experiments of Prof. A. O. Rankine in transmission of sound over a beam of light. The light modulator, in which a rocking mirror caused an image of one grating formed on another grating to move transversely to the bars, appeared well adapted to making photographic records of the variable-density type. While a variable-density record would not give as much information to the eye as a variable-area record, it could be analyzed by instruments of the microdensitometer type. The faithfulness of the recording could be checked by playing it back. (The previous oscillographic recordings had not been designed for playing back.)

Some of the recordings were played in May 1922 for Craft and others. A few months later apparatus-development engineers were requested to construct an electrically interlocking driving system for camera and recorder. Further demonstrations were given in December 1922. In these recordings the principle was recognized, that for linear relations between exposing light and print transmission, the product of positive and negative "gammas" should be unity.[61,62]

Light Valve. The grating type of modulator had several drawbacks, one of which was diffraction by the grating. Because of these difficulties, Wente in January 1923 proposed using a two-string light valve.[63–65,4] Such a valve was ready for test a month later. The tension on the ribbons was adjusted to bring their resonance to 6500 cycles. Condensing lenses imaged the light source on the slit between the ribbons, and an objective lense imaged the valve slit on the film.

Results with the light valve were definitely better than with the previous modulators, and arrangements were made for tests on a larger scale. A recording studio was set up in 1923 and sound pictures made for demonstration purposes.

In the latter part of 1922 and subsequently, much of the study of film emulsions, exposures and developments was carried on by Dr. Donald MacKenzie. He showed that by running the lamp at slightly over-voltage, it was possible adequately to expose positive film, which thereafter was the standard sound-recording stock. The relatively fine grain of the positive stock was of great benefit from the standpoint of resolution and low background noise.

In 1928 MacKenzie described the light-valve model in use at the time, and recording and processing practice (exposure ranges and developments) as worked out at the Bell Telephone Laboratories.[64] The valve is mounted with the slit between ribbons horizontal — so that its image on the film is transverse to the film. The ribbons are in a strong magnetic field and currents in the two are in opposite directions, so that they are deflected (edgewise) to increase or decrease their separation depending on the direction of the current. The width of the slit with no current in the ribbon was 0.002 in., and it was masked to a length of about 0.2 in. It was imaged on the film with a 2 : 1 reduction. With the slit width 0.002 in., the light could be modulated 100% by a vibration of each ribbon of 0.001 in. amplitude. Since the ribbon need be only slightly wider than its double amplitude, thick enough to be opaque, reasonably easy to handle and long enough between supports to make the deflection substantially uniform throughout the length of the slit, it can be extremely light and readily put under enough tension to place its mechanical resonance above the required audio range. Rather than attempting to control the resonance by damping beyond that obtainable electromagnetically, an electrical low-pass filter was used in the input, to prevent the passage of any impulses of high enough frequency to excite the resonance. However the cutoff was not too far below the frequency of resonance to permit a considerable rise in amplitude just before cutoff, the maximum being at about 7000 cycles. This rise was regarded as advantageous in that it compensated for loss of high-frequency response due to image spread in the film. For monitoring, a photocell behind the film picked up some of the light which went through the film.

The subject of sensitometry for soundtracks of the variable-density type also received attention from many other writers for a number of years after the advent of photographic sound.

In the matter of the frequency range attained in the early light-valve recordings, MacKenzie shows an overall (light-valve input to photocell output) curve which was substantially flat to 5000 cycles, a figure not far from what could be obtained at the time with disks.

Recorder. The Western Electric recording machine employed a sound sprocket, having a filtered drive and protected by a feed sprocket from jerks from the magazines.[4] The film was exposed while on the sound sprocket. For synchronism the camera and recorder were driven by selsyn motors.

Soundhead. For reproduction from photographic soundtracks the Western Electric Co. built a "soundhead," to be

mounted under the picture projector,[53–54] similar in many respects to that previously mentioned as used in the Fox-Case development. I shall come back to the subject of the mechanical features of the film-motion system, so shall mention here only some optical and electrical features. The scanning light on the film was an image of a mechanical slit, illuminated by a low-voltage incandescent lamp, with condensing lenses. The filament was a close-wound helix with straight horizontal axis. The photocell and preamplifier were cushion-mounted to prevent microphonic noises. Owing to the very high impedance of the photocell and its small output, a very short (low-capacity) connection to the first amplifier tube is important. The preamplifier brought the level up to about equal to that of the disk pickups.

Standard Speed. In the early theater installations most projectors were equipped for both disk and film reproduction. It was obvious that for sound pictures the recording and reproducing speeds must be closely held to a standard. The practice had become widespread of projecting silent pictures at considerably higher speeds than that of the camera, which had for years been nominally 16 pictures/sec or 60 ft/min. The higher projection speeds shortened the show so that more shows could be run in a day, and the public had become inured to the fast action. But there was a better justification in that flicker was much reduced.

For pictures with sound on film there was further benefit from increased speed in that it resulted in better high-frequency response and, in some degree, reduced percentage of speed fluctuation. A speed of 85 ft/min for silent pictures had been recommended for a standard, but practice varied widely. A speed of 90 ft/min or 24 frames/sec was chosen for both of the Western Electric sound-picture systems (sound on disk and sound on film) and this became the standard. On the theory that exhibitors would demand the option of running silent films at other speeds, the Western Electric engineers adopted a driving system with an accurate control which could be made inactive at the option of the projectionist.[54] Either a repulsion motor or a d-c motor might be used. For 90 ft/min a 720-cycle generator fed a bridge with one arm tuned to 720 cycles. At the correct speed the bridge was balanced, but if the speed was not correct the unbalance gave rise to a correcting current which increased or decreased the motor speed as required.

Commercialization. In January 1927 Electrical Research Products Inc. was formed as a subsidiary of Western Electric and the Telephone Co. to handle commercial relations with motion-picture producers and exhibitors.

The adoption of sound systems by the motion-picture industry (except for the case of Fox Movietone and Warner Vitaphone) is discussed in another section of this paper.

Developments at General Electric Co.

Interest in photographic sound recording at the General Electric Co. in Schenectady stems from the development prior to 1920 of a photographic telegraph recorder for radio reception,[60] by Charles A. Hoxie. Transoceanic radio service was by long waves, and static interference caused the loss of many letters. It was thought that a visual record of the incoming signals, even though mutilated by static, might be deciphered at leisure in many cases in which the signals were forever lost if the operator, depending on ear alone, failed to recognize a letter.

For the usual reception, by ear, the incoming continuous-wave code signals were heterodyned to give interrupted tones of audio frequency, short for dot and longer for dash. Hoxie's recorder made an oscillographic record of these code signal tones, on a moving strip of sensitized paper. Instead of actuating a receiver diaphragm the electrical signals vibrated a reed armature, which, through a delicate knife-edge arrangement, imparted rotary motion to a mirror, which caused a small spot of light to dance back and forth across the sensitive strip.

Since the code recorder vibrated at audio frequency, it was a short step to try it and modifications of it for recording voice, and this was one of the many experiments which Hoxie tried which started him on more systematic experimentation in the field of photographic sound recording. Negative film was used at first, in order to get adequate exposure, but Hoxie was among the first to appreciate the advantage of the finer-grain positive film.

As in the case of the telegraph recorder, the track ran down the middle of the film, and was nearly an inch in width. In Hoxie's recording and reproducing machine the film was drawn over a physical slit on which intense light was concentrated. The width of the slit was about 0.001 in. Since an open slit would quickly fill with dirt, a wedge of fused quartz was ground to a thin edge and cemented in place between the metal edges which formed the slit. The face against which the film was to run was then lapped and polished. A photocell close behind the film picked up the transmitted light, and an amplifier and loudspeaker completed the reproducing system. The results were highly gratifying. Theisen[5] says that Hoxie's first sound recorder was completed in 1921, and with it he recorded speeches by President Coolidge, the Secretary of War and others, and the recorded speeches were broadcast over Station WGY (Schenectady) in 1922.

Hoxie called his optical phonograph the Pallophotophone, meaning "shaking light sound." We do not know the identity of the Greek scholar. In another experimental development, Hoxie caused the vibration of a sound-pickup diaphragm to rock the mirror. This device, called the Pallotrope, was used with a photocell as a photoelectric microphone.

Narrow Sound Track Found Sufficient. Hoxie continued his experimenting for several years before any decision was reached to embark on an all-out program of developing a system of sound for motion pictures. One of Hoxie's experiments which undoubtedly played a part in interesting executives in such a program was that of reproducing with part of his track width masked. The development of the General Electric model of the Duddell oscillograph had centered in the General Engineering Laboratory (where Hoxie worked) and it was extensively used as a laboratory tool throughout the company. With such a background it would be natural to think of a photographic sound track as showing the outlines of the sound waves.

In any case the wide soundtracks made in the Hoxie equipment were of the variable-area type. A spot of light moved parallel with the slit, illuminating a larger or smaller fraction of its length. However, the active edge of the light spot was by no means sharp. While experimenting with reproduction from this sound track, Hoxie observed that masking off part of the track had little effect on the sound except some reduction in volume. He repeated the experiment with still more of the track masked off, until he was using only a sample, about $\frac{1}{16}$ in. wide. This experience was sufficient to demonstrate that a track wide enough to show the wave outlines was by no means necessary for sound reproduction. The narrow strip being scanned was obviously a variable-density record of the sound.

At that early stage of the experimenting we had not seen it demonstrated by actual accomplishment that a satisfactory variable-area recording could be confined within so limited a band, but at any rate this test proved that a photographic sound record could be placed along the side of the picture without stealing more picture width than could be tolerated.

Loudspeaker and Phonograph Developments. Another factor which undoubtedly influenced General Electric executives toward increased interest in sound was the success of the loudspeakers developed by C. W. Rice and myself for broadcast radio reception.[86] The coil-driven (or "dynamic") paper cone, freely suspended, surrounded by a baffle and driven by an amplifier with adequate undistorted power, so far surpassed its predecessors in quality of reproduction that within a few years its use for radio

receivers and phonographs became practically universal.*

Following the loudspeaker development, the success of the electric phonograph helped to make the sound motion picture seem like a logical next project.

Chester W. Rice. I trust that I will be excused if I take this opportunity to pay a brief tribute to my colleague, whose vision and initiative were largely responsible for our undertaking the loudspeaker project. His thoroughness and tireless energy insured that no hopeful lead was left unexplored. He brought to bear on his work an extraordinary measure of ingenuity and mastery of engineering and physical principles, which he was constantly supplementing by study, and his standards of excellence would permit no compromise with an inferior result.

No one could have been more scrupulously fair and generous in giving credit to other workers. His death in 1951 was a great loss to his associates and to science.

C. W. Stone's Leadership. In addition to L. T. Robinson, head of the General Engineering Laboratory, the man who played the major role in initiating and promoting a large-scale project for developing talking pictures, was C. W. Stone, manager of the Central Station Dept., who had taken great interest in all of the sound developments. His enthusiasm, confidence and influence encouraged those who were engaged in development, helped to secure the financial backing and established fruitful contacts outside the company.

Practical designs; Assistance of Prof. A. C. Hardy and L. E. Clark. When, about 1925, a program of developing commercial sound-on-film equipment was undertaken, Robinson was made responsible for the general program, and, together with others in the Research Laboratory, I was asked to assist in problems where there seemed to be call for research. Engineers in the General Engineering and Research Laboratories had had experience in sound, first with loudspeakers[33] and then in cooperation with the Brunswick Balke Callender Co., electrical recording and reproduction for phonographs[53] (the work represented in the Brunswick Panatrope[53] and the Brunswick electrically recorded disks). Our part in the phonograph project was tapering off, freeing some of the personnel to devote time to the newer development. Our group, however, had inadequate background in optics and photography. Professor A. C. Hardy was engaged as consultant and soon did us two invaluable services: he straightened us out on a number of optical and photographic questions, and he recommended that we engage the services of L. E. Clark, then completing some advanced work at Massachusetts Institute of Technology. "Pete's" presence was a guarantee that we would not again get off the beam on optical questions, but his associates at General Electric, then at Photophone headquarters in New York, and later in Hollywood, carry a memory of something far more cherished than his valuable technical help.

Variable-Area System Chosen. A fundamental question on which we took Prof. Hardy's advice was in regard to the advantages of the variable-area type of soundtrack.[61] At the time of Hoxie's tests with a masked track, the only tracks that had been made, sufficiently narrow and still fairly satisfactory, were of variable density. A better understanding and application of optical design was needed to make clear, sharp-edged variable-area tracks within permissible limits of width.[59,60]

With the right kind of lenses and optical design, an imaged slit soon displaced the contacting physical slit with which the first tracks had been made. Hoxie's special galvanometer was not adequately damped, but General Electric had long since been building oil-damped oscillographs of the Duddell type, whose response was good up to 5000 cycles. The optics of the recording system are similar in principle to those of the oscillograph, as explained in one of Hardy's papers.[59] Prof. Hardy had shown how important design improvements could be made, greatly increasing the light intensity at the film. An optical system was designed[60] using a regular oscillograph galvanometer, and following suggestions of Prof. Hardy and of L. E. Clark.

The general mechanical features of the first recording machines were due principally to Hoxie, while H. B. Marvin (of the General Engineering Laboratory) designed amplifiers, optical systems and other necessary equipment. High-quality microphones were available in the Western Electric Condenser Transmitter (developed by E. C. Wente of the Bell Laboratories)[44–47] which was used in broadcast studios and had been an essential tool in the loudspeaker[33] and phontograph developments.[53]

General Electric had a well established motion-picture laboratory under the direction of C. E. Bathcholtz, for general company and publicity service, so that with the cooperation of that department, pictures with sound could be made. A number of demonstrations were given in 1926 and 1927, using this equipment. Motion-picture producers showed interest, but no contracts were made at that time.

An incident of much interest to those who were connected with the photographic recording project was a visit to Schenectady in December 1925 by E. I. Sponable from the Case Laboratories.[6] He showed and demonstrated the combined camera and sound-recording system which he and his associates had developed, giving us the benefit of his experience and participating in some demonstrations. However, no arrangements for combining the efforts resulted.

The Road-Show Wings. The first public entertainment picture to be shown, with the General Electric developed sound system, which by this time had been named the Kinegraphone, was a story of the Air Force activities in World War I, entitled *Wings* and produced by Paramount. The sound effects were added after the picture had been shot. The system and equipment were demonstrated and briefly described by H. B. Marvin.[67]

Wings was exhibited in 1927 as a "road show" (about a dozen sets of equipment having been supplied), for few motion-picture theaters at the time *Wings* was shown were equipped for optical sound reproduction. Multiple-unit cone-and-baffle type loudspeakers[33] were used, with a bank each side of the screen. The sound-reproducing device or "head" was mounted on the top of the projector, no standard sound offset having been established at the time the apparatus was designed. The picture width was reduced from 1 in. to $\frac{7}{8}$ in. to make room for a soundtrack. Ninety ft/min had by this time been agreed upon for film speed.

There were many, even of the most enthusiastic advocates of sound-picture development at General Electric, who did not think of the chief function of the synchronized sound as giving speech to actors in plays, but there was high confidence that there was a large potential market for sound systems for furnishing sound effects and background music and providing voice for lectures and speeches.

G.E.–Westinghouse–RCA Working Arrangements

At the time that the synchronized sound development was taking shape, the three-cornered arrangement between General Electric, Westinghouse and RCA was in effect. RCA was the sales outlet for all radio and kindred equipment. Manufacturing was divided between General Electric and Westinghouse. Research and development continued to be carried on at both manufacturing companies, and before production was

* Many of the elements of this type of loudspeaker, such as coil drive, cone diaphragms and the baffle had been proposed individually by early inventors, but not in the full combination. Nor, I believe, was the principle of placing the mechanical resonance of the diaphragm (with its suspension) at or below the lowest important frequency proposed, except that Adrian Sykes (U.S. Pats. 1,711,551. and 1,852,068) advocated it for a microphone. The Farrand loudspeaker (U. S. Pat. 1,847,935, filed 1921. See Radio Club of America, Oct. 1926) had a large cone, coil-drive and low resonance-frequency, but no baffle or associated power amplifier. It had considerable commencial success during the 1920's.

started, designs were coordinated between them and had also to be acceptable to RCA, which maintained a Technical and Test Dept. in New York, to pass on performance.

At Schenectady, in view of the prospects of manufacturing on a much larger scale than could be handled in the General Engineering Laboratory, the film project had been transferred (1927) to the Radio Dept. where it was under the direction of E. W. Engstrom. The change brought new personnel into the activity. The names of E. D. Cook and G. L. Dimmick deserve mention.

Developments at Westinghouse

Engineers at the Westinghouse Electric and Manufacturing Co. in East Pittsburgh did not turn their attention to photographic sound recording until about 1926 when the project at Schenectady had gained some momentum.

One of the first research projects undertaken was to adapt the Kerr cell to photographic recording. The development was described to this Society in 1928 by V. K. Zworykin, L. B. Lynn and C. R. Hanna.[68] Nitrobenzene has the property of rotating the plane of polarization of a light beam, when the liquid is subjected to an electrical field at right angles to the direction of the light. The amount of rotation depends on the square of the field gradient. Practically, several hundred volts per millimeter are required. Nicol polarizing prisms are used on each side of the cell and rotated to extinguish the light at minimum applied voltage. With increase of voltage, the transmitted light then varies as the sine of the increase in angle of rotation.

One of the design problems is to keep within satisfactory limits the distortion resulting from the nonlinear relation between voltage and transmitted light. Another difficulty is that commercial nitrobenzene is yellow, absorbing the photographically valuable blue light. The investigators were able by double distillation to reduce very largely the absorption of blue light. A third problem was avoidance of electrical arcs through the liquid, which quickly contaminate it. Proper choice of electrode material and surfaces, and purification of the liquid made it possible to produce cells which were regarded as practical.

The unique property of the Kerr cell light modulator which makes it of special interest is its extreme speed. The only limitation is in the ability of the modulation-voltage supply system to charge the extremely small capacity of the cell. As contrasted with this, other light-modulation systems either involve moving mechanical elements, or electrical discharges through gases, which have definite frequency limitations.

Zworykin, Lynn and Hanna were in the Westinghouse Research Laboratory, which was under the direction of Mr. Kintner. A group under Max C. Batsel was responsible for development and design of commercial equipment. One of this group was J. D. Seabert, whose contribution to the theater loudspeaker problem will be described in the paragraph with that heading. Hanna's analysis of the damped flywheel problem[69] laid the foundation for the highly successful rotary stabilizer discussed under that heading in the section dealing with Mechanical Systems.

Organization of RCA Photophone, Inc.

RCA Photophone, Inc. was organized in 1928 as an RCA subsidiary to carry on commercial exploitation of the sound-on-film system. Carl Dreher (later with RKO) was its first chief engineer, followed in 1929 by Max C. Batsel from the Westinghouse Co. A laboratory was established in New York to which a number of engineers were transferred from the Technical and Test Dept. of RCA.

New Designs of Commercial Units. Between the launching of the *Wings* show and the offering by RCA Photophone, Inc., of a commercial sound system,* a number of design changes and advances had been made. C. L. Heisler had designed a new recording machine (R-3) and a combined picture and sound projector (P-2),[70] both of which embodied new principles in film motion. A sound attachment or "soundhead" was developed, by which existing silent projectors could be adapted for sound. The offset between picture and sound had meantime been standardized at 14½ in., with the soundhead mounted under the projector. Because of the much more stringent requirement for accurate and constant speed for sound than for picture, the driving motor was made part of the soundhead, and the projector mechanism driven from the soundhead through gears. The first commercial soundhead to be offered by the RCA group (designated as PS-1) was of Westinghouse design, but the manufacturing was carried on by both companies.

Theater Loudspeakers. The flat baffle type of loudspeaker[38] used in the *Wings* equipment and in almost universal use for home receivers, while excellent for music and sound effects, had not proved satisfactory for *speech* reproduction in reverberant theaters. While a certain kind of directivity can be had by using arrays of direct-radiator loudspeakers, vibrating in phase, this did not confine the radiation in the direction of the audience as successfully as the use of short horns. The first successful units of this type were developed by J. D. Seabert in 1929 (then of Westinghouse). The horns used at first expanded from about the cone area to an opening abut 3 ft by 4 ft. The name "directional baffle" was used to distinguish these horns, whose primary function was to confine the radiation within a limited angle, from the small-throat horns whose basic function was to load the diaphragm, in addition to confining the radiation. The directional baffle type of unit was the subject of later developments by Dr. H. F. Olson and his associates.[71–73]

In spite of the benefits of directive baffles, in many motion-picture theaters satisfactory speech reproduction was not achieved until absorption had been applied to reduce reverberation.

Location Equipment. The RCA equipment also included a truck for location and newsreel service.[75] With batteries for power supply, the truck carried a motor generator for driving apparatus designed for 60-cycle operation, and a studio-type film recorder, to be driven in synchronism with a cable-connected camera. For more remote or inaccessible locations, a single-film system was provided, with portable batteries and amplifier, governed direct-current camera motor, and a sound attachment, mounted on the top of the camera.[74] The first commercial uses of RCA Photophone recording equipment were for newsreel service. Two types of light modulator were employed in the earliest Photophone single-film location equipments, one of which used a galvanometer designed by W. O. Osborn and K. A. Oplinger, under the direction of C. R. Hanna, with optics generally similar to those of the studio system, and the other the Kerr cell (or Carolus cell) system developed by L. B. Lynn and V. K. Zworykin.[68]

Location equipment (sound trucks) of improved design followed within a short time. Of special interest was a new optical system requiring only 3 w for the lamp.[76]

Disk Equipment. Although the RCA group was convinced of the inherent advantages of sound on film for motion-picture sound, disk equipment was wanted in all of the earlier theater installations, and accordingly combined sound-on-film and synchronous disk equipment was designed and built by the G.E. and Westinghouse companies and supplied by RCA Photophone, Inc.

A number of developments and inventions took place at both of the manufacturing companies which did not come into commercial use for several years, and these will be described presently.

Commercialization. The establishment of commercial relations with picture producers is described in the latter part of the following section.

* H. B. Franklin in *Sound Motion Pictures*[3] gives May 14, 1928, as the date of an announcing advertisement in New York and Los Angeles papers; however the Progress Report, *Trans. SMPE*, No. 31, 438, May 1927, states that Photophone equipment is to be sold direct to theaters, and that recording efforts would be concentrated on music scores.

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Another installment of this paper will be published in the July Journal

A Compatible Photographic Stereophonic Sound System

By JOHN G. FRAYNE

This paper describes a 2-channel photographic stereophonic system, variable-density and variable-area, the two soundtracks occupying the same position as the normal single track on release film. Methods of recording using either a straight 2-microphone or an alternate system with a bridged center microphone are described. Methods of reproducing over a 2-loudspeaker or over a 3-loudspeaker system with the center bridged to the outer two are described. Tracks recorded in this manner may be played over standard theater systems equipped for single soundtrack only. Standard single tracks may be played over this system by means of a simple operating change in the booth.

Several stereophonic sound systems have been introduced by the motion-picture industry within the past few years, with generally favorable acceptance by motion-picture audiences. In this paper we shall define stereophonic sound as that which preserves in reproduction the spatial characteristics of the original sounds as picked up on the motion-picture stage and reproduced by a plurality of loudspeakers. It was shown by Steinberg and Snow[1] in 1934 that this type of sound reproduction could be obtained with as few as two or three sound channels beginning with microphones and ending with loudspeakers. A 3-channel photographic system on separate film was demonstrated to the motion-picture industry by the Bell Telephone Laboratories in 1940 with highly gratifying results, but several years elapsed before the industry gave serious attention to using this method of sound recording in its picture presentation.

The first known commercial use of stereophonic sound made in accordance with the above definition was that employed in Cinerama in 1952 when five magnetic tracks on a separate 35mm film were used to produce the stereophonic effect. In 1953, following the lead of Cinerama, a 3-channel stereophonic system on a separate 35mm film was used as an adjunct to the presentation of 3-D pictures. This system was widely referred to as stereophonic, but in most cases the effect could be characterized as a pseudo-stereophonic one. The motion-picture studios did not have time to develop the techniques of stereophonic pickup on the stage, and most of the dialogue was moved across the stage by means of pan-potting an original monaural soundtrack. The music was in general more nearly true stereophonic, although here again techniques employed for years on monaural pickup were largely retained. The overall result was more nearly what might be called "spread" sound rather than true stereophonic.

In 1953 the first real attempt at stereophonic sound using a composite 35mm film was made with the introduction of CinemaScope by Twentieth Century-Fox. In this case, four magnetic tracks were striped on the composite release film, three of them being employed to produce a stereophonic effect and the fourth being used to provide auditorium sound effects. In the CinemaScope system, a real attempt was made by Twentieth Century-Fox to record the entire production, both dialogue and scoring, on a true stereophonic basis. In the meantime, other motion-picture studios have produced many pictures in CinemaScope, but in most cases the dialogue cannot be classed as stereophonic since it was mainly derived by pan-potting the original single monaural track.

All the systems described above require special reproducing facilities in addition to the extra transmission and loudspeaker facilities called for by stereophonic reproduction. In general, therefore, films made with these systems cannot be played in nonequipped theaters and for this reason they must be considered noncompatible. In other words, a CinemaScope release print with four magnetic tracks can under no circumstances be reproduced in a theater equipped only for single-track photographic reproduction. To meet, in part, these objections, Perspecta sound was introduced in 1954. In this system a single monaural track associated with three subaudible control frequencies makes possible the movement of sound across the screen quite similar to that produced by pan-potting on the CinemaScope and other systems. This system is basically a monaural system and does not come within the scope of the above definition of stereophonic sound as envisaged by the originators of this method of recording. It may be described as functioning for one sound for one position at a time, and therefore all sounds that occur simultaneously move together to whatever position for which the controls are set at the particular time. The fundamental difference between single monaural pickup and that provided by two or more independent pickups must not be lost sight of in understanding the basic difference between monaural and stereophonic sound.

A compatible stereophonic system must be photographic or optical in make-up. It must occupy the same position on the release print as the standard optical track. It must be capable of being reproduced in a non-equipped house. Conversely, standard optical prints should be capable of being reproduced in an equipped house with either no or very slight operational changes. Although 3-channel stereo systems are widely accepted in the industry today, the Bell Telephone Laboratories scientists of 1934 are on record as saying that a 2-channel system gives closely comparable performance, es-

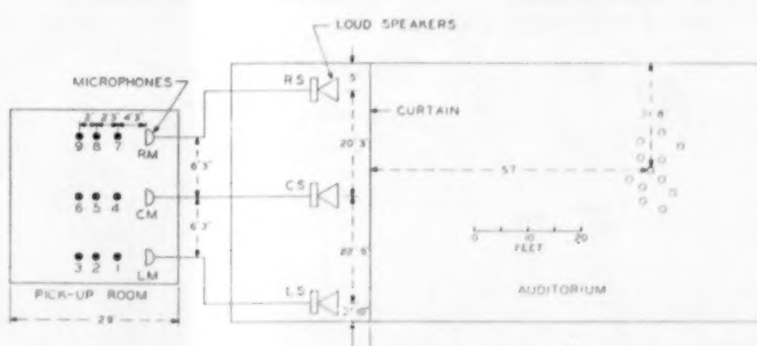

Fig. 1. Bell Telephone Laboratories arrangements for stereophonic localization tests.

Presented on October 21, 1954, at the Society's Convention at Los Angeles, by John G. Frayne, Hollywood Div., Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.
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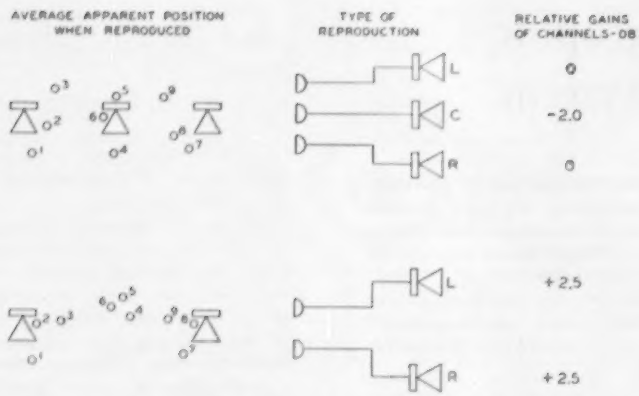

Fig. 2. Comparison of 3-channel and 2-channel stereophonic pickups.

pecially as far as angular localization of the sound is concerned. The system employed at the Bell Telephone Laboratories in determining the stereophonic performance of various systems is shown in Fig. 1 and was republished in detail in the *Journal* in 1953.[3] The microphones—left, center and right—were set on a "pickup" stage that was marked out on the floor of an acoustically treated room. The loudspeakers shown in Fig. 1 were placed in the front end of the auditorium at the Bell Telephone Laboratories, being concealed from view by a curtain of theatrical gauze. Twelve observers took part in the tests, their average position being shown by the adjacent arrowheads in the rear center part of the auditorium. The small diagram at the left of the Fig. 1 shows the caller's position with respect to the three microphones on the stage. The corresponding average positions as determined by the twelve observers for different microphone and loudspeaker arrangements are shown in Figs. 2 and 3. For example, a comparison of the performance of a 3-channel and a 2-channel system is shown in Fig. 2. Apart from providing less depth, which apparently is relatively unimportant in motion-picture presentation, to pick up at the center of the stage, the 2-channel system seems to perform quite favorably from a stereophonic sound standpoint compared to the 3-channel, giving actually wider angular localization. A variation of the 2-channel system with a bridged center loudspeaker channel as depicted in Fig. 3 results in somewhat greater depth, especially at the extremities of the stage, but appears to have little effect on the sound apparently coming from the center of the screen.

In view of the apparent efficiency of a 2-channel system, it would appear unnecessary and unduly complicated to provide for more than two photographic tracks in the rather limited area allotted at the present time to the standard single track. It is, of course, physically possible to record and reproduce from three separate optical tracks in this restricted area, but there are many practical difficulties and limitations to be overcome. For example, in the case of variable-area tracks, a maximum of about 24 mils could be allotted to each individual track. This would entail a level loss in excess of 10 db for each track and a reduction in signal-to-noise ratio of at least half that amount. The optical system necessary to scan three individual tracks becomes very complicated, and it is doubtful if such a system could be successfully incorporated in many existing soundheads. On the other hand, with a 2-track system which entails a level loss of only 6 db on each track, the readily available 100-mil push-pull optics can be installed without great difficulty in the existing soundheads. Double-cathode push-pull cells are available, whereas triple-cathode cells would have to be specially developed for a 3-track system.

The system described in this paper, which we shall refer to as PhotoStereo sound, uses two optical tracks, which may be either variable-density or variable-area. The dimensions and locations of the tracks are shown in Fig. 4. It will be noted that a septum of 4 mils is provided in each case between the two component tracks. The component tracks are recorded in line and, of course, are reproduced in line. In making the original recordings for the 2-track system, either a 2- or 3-track magnetic original may be made. In the case of dialogue pickup on the stage, experience has shown that a 2-microphone pickup gives excellent performance. It has also been shown that two microphones can be mounted on a cross-arm on a single boom requiring the service of only one operator. The spacing between the microphones should be under the control of the boom man, being spread out where the actors are far apart on the stage and being drawn closer together where the actors are in close proximity to each other. In the case of the pickup of the large orchestra, a 3-microphone pickup may be preferable to two if sufficient coverage cannot be made by a 2-microphone setup.

To reproduce the PhotoStereo system, an optical arrangement in the soundhead similar to that used in 100-mil push-pull systems is used, a typical arrangement being shown in Fig. 5. The relay lens mounted behind the film focuses the tracks on the separator lens assembly. The split lens assembly serves to separate the component light beams and at the same time provides separate images on the two cathodes of the exit pupil of the relay lens. This not only ensures proper track separation but also provides the intensity type of scanning that is important in reproduction of variable-area tracks.

A simplified block schematic of a typical PhotoStereo reproducing system is shown in Fig. 6. Each cathode of the push-pull cell is connected to an independent photocell amplifier. The outputs of these two amplifiers are fed through a dual fader to independent power amplifiers and to independent loudspeakers placed behind the screen and symmetrically located with respect to the screen center. This is a 2-channel stereophonic system, and although it has sometimes been referred to as "binaural," this term is not in accord with the definitions which were proposed by the

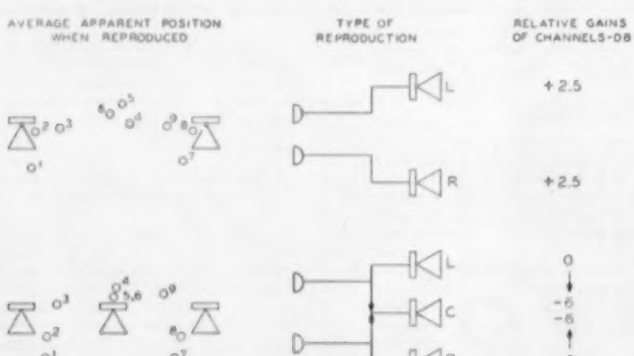

Fig. 3. Two-channel compared with 2-channel with bridged center channel stereophonic reproduction.

original authors and which are followed in this paper. In practice the two channels should be lined up with a suitable test film so that the gain differential is less than 1 db. The frequency response should similarly be held to very close tolerances.

An alternate to the above system is shown in the broken lines in Fig. 6 in which the output of the two photocell amplifiers is bridged to a third or "phantom" center channel. The bridging network to create the third channel is shown in detail in Fig. 7. In this case, three power amplifiers and their associated loudspeakers furnish what has come to be known as a 2½-channel stereophonic system. The insertion loss between left and right photocell amplifiers and their associated power amplifiers is 11.3 db. The loss between left and right channels and the center channel is 17.3 db, and the net loss between left and right channels is 35 db. The latter gives sufficient isolation between left and right channels to effectively eliminate crosstalk between the channels. In addition to these losses, the use of a half-track results in an extra loss of 6 db per channel. The resulting total channel loss of approximately 18 db must be corrected by supplying new photocell amplifiers of increased gain or by the addition of an extra amplifier in each channel.

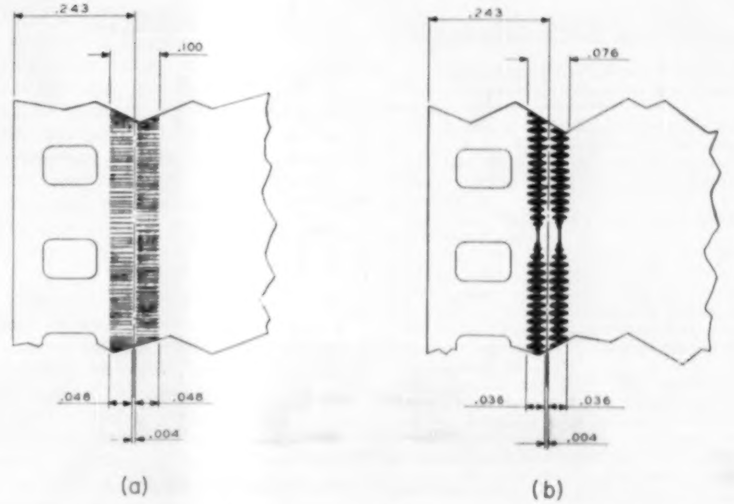

Fig. 4. (a) Variable-density PhotoStereo tracks; (b) variable-area PhotoStereo tracks.

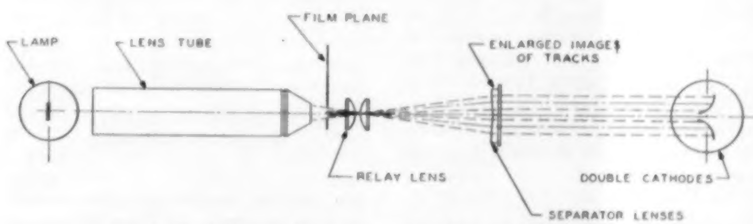

Fig. 5. Optical scanning arrangement for PhotoStereo tracks.

In the schematic shown in Fig. 7, the left and right channels are bridged into the center channel with a relative attenuation of 6 db. With this arrangement and with equal signal levels of program material on the two soundtracks, a good balance of auditory perspective is attained. To permit adjustment of the center-channel level to secure a particularly desired stereophonic distribution, a variable attenuator may be inserted in the center channel to control its gain relative to that of either side channel.

For the reproduction of a standard soundtrack on this system, means can be provided for diverting all the transmitted light flux onto one of the component cathodes of the push-pull cell, at the same time switching the output of the associated photocell amplifier to the center channel. This can be accomplished in one operation—the optical switching device closing a contact that operates a relay to perform the necessary switching. In the event of failure of the operator to perform the switching operation, a standard soundtrack would be reproduced over all the loudspeakers. In the case of the variable-density track, no distortion should result with this type of reproduction, except perhaps undesirable acoustic effects from the use of three speakers, each being supplied with equal signal strength. In the case of variable-area track of the single bilateral type in which the low-level modulation exists at the center of the track, it is quite probable that severe distortion and attenuation of low-level sounds would result. The more popular type of double bilateral or duplex variable-area track could probably be reproduced with the same fidelity as variable-density sound.

Recording Techniques

The production of 2-channel PhotoStereo sound on the stage is a relatively simple matter. Two microphones, preferably nondirectional, are mounted on a cross-arm attached to a standard microphone boom. For flexibility in scenes requiring considerable motion on the set, it is quite important that the distance between the two microphones be adjustable. For example, they should be wide apart for those parts of the scene in which the actors are widely separated on the stage, and they should be moved closer together as the action is concentrated on any particular area of the stage. In order to obtain true stereophonic location of the actors in relation to the picture on the screen, it is necessary for the mixer to work in very close cooperation with the cameraman to ensure that the camera axis at all times bisects the distance between the two microphones. After the levels for each microphone are set following a rehearsal, the individual gain of each channel should not be altered and only a ganged overall gain control should be used. The

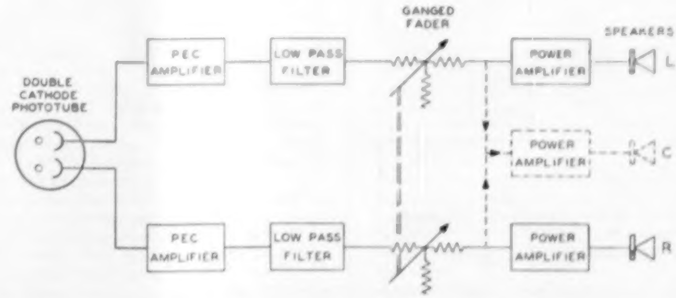

Fig. 6. Stereophonic reproducing channels for 2-and 2½-channel systems.

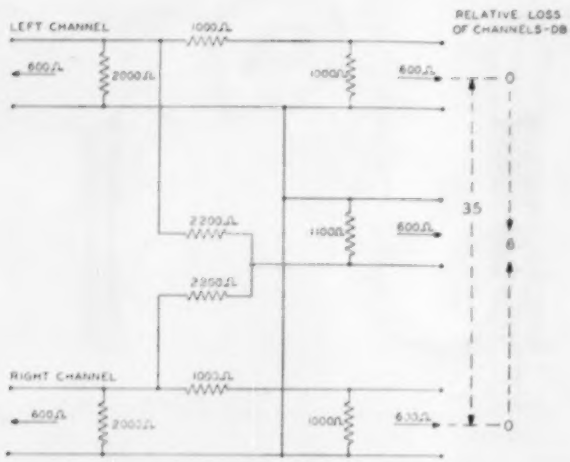

Fig. 7. Combining network for bridged center channel.

changing of the individual channel gain may result in completely upsetting the acoustic perspective, causing the actors' voices to come from wrong parts of the stage.

The recording equipment used in this 2-channel system is quite similar to that described by Frayne and Templin[8] with the exception that only two preamplifiers are employed and that the two outer magnetic tracks on the 35mm film are energized, the center track being left blank. For 3-channel original recording, such as might be used for orchestras or large scenes, the technique is exactly that practiced for normal 3-channel recording. In either 2- or 3-channel production recording, it seems to be quite important that nondirectional microphones be used; otherwise the action will appear to be "jumpy" as the actor moves in and out of the microphone pattern.

Re-Recording

In this operation the outputs of either 2- or 3-channel pickups are combined into a 2-track magnetic master for final transfer to a photographic negative. The method of combining the 3-channel output into a 2-channel recording is shown schematically in Fig. 8. The output of the center channel is divided equally between the left and right channels. With the network values shown in the figure, the insertion losses in the left and right channels are the same as the losses between the center and side channels and amount in each case to 24.5 db. The loss between the input of either side channel and the output of the opposite channel is 73.5 db, or a net isolation of −49.0 db. This gives practically complete isolation between the two stereophonic channels. In addition to correcting for level variations between the various tracks being rerecorded to the final master, certain corrections can be made for errors in the auditory perspective by simply altering the gain of the individual channels. Thus, if in a scene the actor's voice should seem to come from the left while the picture shows him in the center of the stage, a slight reduction in the gain of the left channel or simultaneously a slight increase in the gain of the right channel may produce the desired movement. In contrast to pan-potting of monaural tracks to produce movement on the stage with a true stereophonic pickup, it has been found that only very small changes in gain will result in considerable movement on the stage.

When a 2-channel or binaural system is to be used for reproduction in the theater, then a 2-channel, 2-loudspeaker system should be used for monitoring in the re-recording process. When 3-channel reproduction is envisaged, then a 3-channel monitor should be employed. With the limited experience available with this system, the same mixer-pot settings appear to be correct for either system of reproduction. Listening tests appear to confirm the Snow-Steinberg

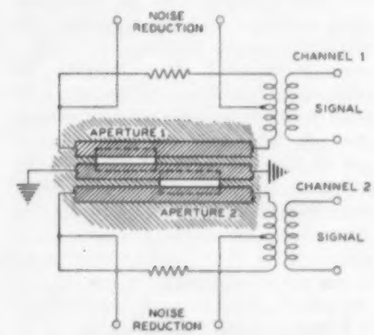

Fig. 9. Stereophonic light valve for variable-density track.

data in that the bridged third channel appears to lessen the "spread" of the sound over the screen, keeping the apparent sounds more solidly in the center of the screen. The 2-channel system when used throughout from microphone to loudspeaker results in excellent stereophonic definition, but does have a somewhat "floating" characteristic in which the perspective may change very rapidly with gain in either channel. The addition of the bridged center channel for reproduction appears to tie in the sound more closely in relation with the picture as viewed on the screen.

Phototransfer

Having completed the 2-channel magnetic master, the next step consists of transferring these channels to the final photographic release negative. Since it is important to keep the modulation of the two component tracks exactly in line, the technique that has been practiced elsewhere of recording first one channel, rewinding the photographic negative, moving the modulator and then recording the second channel has been found to be quite unsatisfactory

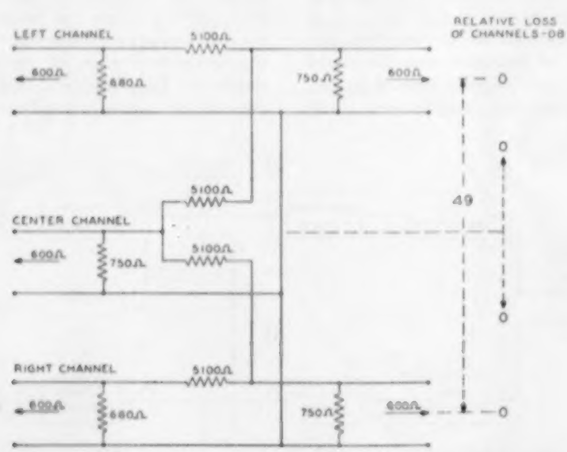

Fig. 8. Network for bridging center channel to left and right channels.

owing to resulting phase shift between the tracks. To ensure exact recording in line of the two component tracks, a special light-valve arrangement has been developed for both variable-density and variable-area track. In the variable-density method a 3-ribbon type of push-pull valve previously described in the *Journal*[4] has been modified to provide two independent tracks. This is done as shown in Fig. 9. The center ribbon, which in push-pull operation is used to modulate the signal, is now simply retained as a mask. The two side ribbons, which normally carry only noise-reduction currents, in this case carry both signal and superimposed noise-reduction currents. Since the two apertures of the light valve are brought exactly in line by means of optical compensators mounted in the valve, the two resulting stereophonic tracks will be exactly collinear. The individual transmission channels connecting the output of the master magnetic reproducer and the individual light valves are quite similar to those employed in normal photographic recording of this type.

For variable-area sound, a special light valve having four ribbons and capable of laying down two complete bilateral tracks has been developed. These tracks are also collinear, just as in the case of the density light valve. In making the variable-area recording, standard variable-area recording techniques are followed just as they would be for single or monaural sound recordings. The film processing of each individual track is identical with that which would be followed for a normal full-width photographic track. Since the negative is a normal photographic one, normal contact printing may be employed without the added cost of striping and re-recording of each print necessary where magnetic striping of the release print is practiced. For variable-density sound, it is important that the density of the two component tracks be of nearly equal value to prevent shifting of the stereophonic pattern due to unequal channel gains. A variation of as little as 1 db will sometimes cause an apparent shift from the visually depicted scene. For this reason a density variation of less than 0.05 between tracks is highly desirable.

Limited experience with the PhotoStereo system to date indicates that satisfactory reproduction can be obtained from two tracks located in the standard track position. Two-channel reproduction is quite satisfactory, but a third or bridged channel can be employed, especially on wide screens. It has been found that when the dual tracks are scanned in a normal monaural type of reproducer, some loss in quality occurs, but not to a degree that would be considered unsatisfactory reproduction. Further, standard prints may be reproduced in theaters equipped to play PhotoStereo tracks by diverting the total light flux onto one cathode of the double photocell. In houses equipped with two loudspeakers, the signals can be switched equally to both speakers. In a house with a center loudspeaker, the signal can be switched to this speaker for normal monaural reproduction.

Following the presentation of the paper, a demonstration was given of a 2-channel stage recording of a re-enacted scene from Samuel Goldwyn's *Best Years of Our Lives*, and a 3-channel original recording of a 48-piece studio symphonic orchestra playing the overture to the *Barber of Seville*. These were played over a 2-loudspeaker system and repeated over a 3-loudspeaker system. To demonstrate compatibility, the tracks were then reproduced on a standard single-channel reproducer.

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Discussion

R. T. Van Niman: It seems to me that you are getting the same effects here that we have observed for quite some time with so-called binaural recording. I did not notice any particular centering of the action on the screen.

Dr. Frayne: I agree that we have a lot to learn about stereophonic pickup of dialogue. On the second matter I feel quite confident that the cost of modifying optical soundheads for this type of reproduction would be relatively low.

Col. Richard H. Ranger (Rangertone, Inc.): On the three microphones, I agree with you that they are fundamentally correct. I think that dates way back to the original work, but I wonder about the three speakers. I have tried my best to make the center speaker really perform effectively as against the two on the outside using two recorded channels only and I have great difficulty doing it. The center speaker does not seem to add to the perspective. I just wonder what your experience has been. I agree with the three microphones, however. I think it's correct.

Dr. Frayne: Although this reproduction sounds quite satisfactory with just two speakers, the fact remains that a center speaker is desirable for a binaural track. I think three speakers are indicated for a practical reason if for no other reason.

George Lewin (Signal Corps Pictorial Center): Don't you think that weave of the soundtrack will cause changes in sound placement?

Dr. Frayne: The width of the septum could be set so as to minimize weave, which is not too important anyway in stereophonic reproduction.

Mr. Lewin: Well, if it changes the level from either track, it is going to move the sound.

Dr. Frayne: Possibly but just cutting over from one side to the other is not too important from the crosstalk standpoint.

Mr. Lewin: Suppose it weaves enough so some of the peaks are cut off, when variable-area track is used?

Dr. Frayne: Then we go to variable-density. I do not think weave is a great problem in modern equipment.

Mr. Van Niman: How critical is the gain stability in the two channels involved? In other words, how much can the channel gain vary without throwing off the auditory perspective, as you call it?

Dr. Frayne: Well, I don't really know. Maybe Mr. Snow can assist.

William B. Snow (Consultant): I do not think it would be particularly critical. A 2-db difference between channels might shift the angular localization about 15% of the loudspeaker separation.

Dr. Frayne: Thank you, Mr. Snow. I was going to say the same thing but I thought I should refer the question to the expert.

Mr. Snow: I was much interested in Dr. Frayne's paper because I have championed the worth of 2-channel stereophonic reproduction for many years. I feel that the sudden and enormous jump in realism takes place in going from one channel to two channels, because in this case we get both the sense of space and the quality improvement characteristic of stereophonic reproduction. The latter effect is subjective and so far has not been adequately explained physically, but it certainly can be demonstrated. Additional channels certainly improve the effect, particularly in practical use in motion pictures, but I feel that the biggest step is from one to two channels. Where economy is of great importance 2-channel reproduction should be considered seriously.

L. J. Raskin (NBC): You mentioned that in one of the scenes the microphones were not moved. Was this in the dramatic scene?

Dr. Frayne: No. They were moved in the dramatic scene. They were moved apart and brought together with the action. But there wasn't much following.

Mr. Raskin: In other words, no attempt was made to move them with changes in the camera position?

Dr. Frayne: Yes, they were moved with the camera. Every time the camera moved they were changed in order to keep the perspective.

Lorin D. Grignon (Twentieth Century-Fox): You described a modification of the optical soundheads.

Dr. Frayne: Yes, sir.

Mr. Grignon: I was surprised to learn recently that a great number of universal base curved gates are still in the field. Are these amenable to modification?

Dr. Frayne: Yes, but we hope it will not prove to be necessary.

Anon: Over what physical range did you play the microphones? That is, how far apart were they spread in the dramatic scene and how close together?

Dr. Frayne: Oh, I'd say in the scene where the girl is talking to the boy quite closely, the microphones were not more than a couple of feet apart, and then they were moved eight or ten feet, something like that, for the wide scene where the girl is in one corner of the room and the chap is on the other side.

Ralph E. Lovell (NBC): Do you have both variable-density and variable-area methods available?

Dr. Frayne: Yes.

Mr. Lovell: Is this merely to show that it can be done by either method or would you recommend density for a particular application and variable area for others?

Dr. Frayne: Variable density would be more desirable from the standpoint of weave but would be inferior to variable area from the standpoint of signal output and signal-to-noise ratio. Reduction of the background noise in the variable-density tracks could be achieved by resort to pre- and post-emphasis. Better yet would be the achievement of a finer grain positive film than we have today.

John T. Mullin (Bing Crosby Enterprises): Was the relatively high background noise which we did hear attributable to the use of narrow tracks?

Dr. Frayne: Yes.

Mr. Mullin: Is the major scource of noise in the original film or would it be mostly due to the narrow tracks of the optical release print?

Dr. Frayne: That is quite so. The noise of the original magnetic channel is inconsequential.

Ralph H. Heacock (RCA): I understood, or you intimated, that if the industry was interested considerable improvement could be made in optical recording. Are you convinced that if there was interest and if you spent some time on it that you could have or could make optical recordings that would equal the present quality of magnetic recordings both operating at 90 feet per minute?

Dr. Frayne: Before attempting to answer that question, let us first analyze the differences between magnetic and photographic recording. Magnetic tracks are considerably quieter than photographic and they have a somewhat better high-frequency response for the same film velocity. When it comes to flutter, photographic has at least a theoretical advantage in that the problem of pulling a film over a fixed gate is eliminated. One of the big advantages in magnetic is that each print is an electric transfer from a master. In photographic, the positive soundtrack is made by contact printing from a negative—a process which is known to result in high-frequency losses, in increased flutter and amplitude modulation. If each print were made by a direct-positive transfer, then we should have a much improved optical print. More research in finer grain films and recording techniques is needed if the industry wants improved optical sound performance.

Mr. Heacock: Does it seem reasonable to you that with a reasonable expenditure in engineering, considering that magnetic recordings are relatively new, we might get more for our money by developing and perfecting magnetic recording rather than continuing with the optical recording upon which you and many others have already spent a good many years trying to get them better?

Dr. Frayne: Well, that is a good question.

Mr. Heacock: Maybe I am way out in left field, but I have a feeling that we are just at the beginning of the magnetic recording. We have had a long time to work on optical recording. Do you think this feeling is in error?

Dr. Frayne: I might say that magnetic recording has been in the field since around 1898.

Mr. Heacock: But nothing was done about it until the last few years.

Dr. Frayne: Oh, I am sure that magnetic recording will be improved. There is no question about it, but the basic thing is this as I see it and I had not intended to go into this discussion but I can't avoid it. As long as we have a photographic emulsion with a picture on it, that photographic emulsion is a perfectly logical vehicle for a soundtrack.

Now, if you decide to abolish the photographic emulsion for picture and use a magnetic medium to get a picture, then I would say "go ahead and forget about photographic recording," but I do not think we should forget about photographic recording as long as we have a picture on the same film. From the economic point of view, as long as we have photographic emulsion it seems advisable to try and make good use of it for sound also.

Mr. Grignon: Are you disapproving of magnetic CinemaScope release?

Dr. Frayne: Not at all. The original reason for using magnetic on CinemaScope was not because it was magnetic but because it enables you to record and reproduce more tracks much more easily than you could possibly do in the photographic medium.

Mr. Mullin: Is the reason why he could not get more tracks due to the limitations of the photographic recording method?

Dr. Frayne: It was decided to use four tracks on CinemaScope and it seemed extremely difficult to put four optical tracks on a film and reproduce them in the theater. It would be difficult to modify all of the various types of soundheads in the world and it would be extremely difficult to agree on a standard. So the only thing to do was design a new magnetic soundhead. I think CinemaScope swung to magnetic on practical considerations.

Mr. Grignon: That is a reasonable statement, at least it is part of the story; but further, we wished to immediately enjoy the improved sound reproduction available with magnetic methods.

Edward S. Seeley (Altec Service Corp.): I believe the center is considered the most important position in all dramatic sequences. The work of Bell Telephone Laboratories established quite clearly that presence is lost for center-screen dialogue if the center channel is omitted.

Dr. Frayne: It is my feeling that there is plenty of action in the center of the screen. Unfortunately, the industry has had little experience with stereophonic pickup of production dialogue since it relies mainly on pan-potting of monaural dialogue to produce a pseudo-stereophonic effect.

Mr. Grignon: I want to point up one characteristic of this compatibility idea. The proposal is essentially the same as those which are sometimes used for the reproduction of CinemaScope stereophonic sound on single reproducer systems—frequently referred to as "mixers"—in which the signals from all tracks are arbitrarily combined into a single channel. We know very well from experience that you cannot combine two or three stereophonic tracks by mixing them indiscriminately, or by reproduction in parallel, without suffering curious and unpredictable losses in sound quality to a serious extent.

Dr. Frayne: That is probably true, and in that sense the system described in the paper is not truly compatible. I might add in closing that the proposed system is not to be considered in any way competitive with 4-track magnetic CinemaScope but merely points out the possibilities of a 2-track photo-stereo system that could be reproduced in standard optical soundheads with a minimum of modification and addition of special equipment.

Stereophonic Sound Reproduction Enhancement Utilizing the Haas Effect

By BRUCE P. BOGERT

This note describes a way to implement the spatial recognition of sounds in a stereophonic sound-reproducing system by using a large sound projector to supply the required acoustic level, and lower power loudspeakers to produce the spatial effect.

The current interest in stereophonic sound systems, both in the motion-picture industry and more recently in radio broadcasting and the high-fidelity field, makes it worth while to consider methods to implement conveniently the spatial recognition of sounds. One such method will be discussed here and has particular application to the motion-picture theater sound system, as it involves the use of a large sound projector to supply the required acoustic level, with lower power loudspeakers to produce the spatial effect.

In the ordinary stereophonic loud-speaking sound system, separate microphones pick up the sound from two or more locations, and the signals are transmitted or recorded in some fashion, to be reproduced by means of loudspeakers spatially separated. In a typical case, three microphones are used, with their output recorded on three soundtracks. These soundtracks are played back into three loudspeakers, located at the left side, the center, and the right side of an auditorium stage. Each of the sound channels has the same power capacity, in general, since the maximum sound-level requirement for each is similar.

The method to be discussed makes it possible, by inserting a small time delay in one channel, to reduce the power capability of the other sound-reproducing channels. We consider only the sound-reproducing part of the entire system, and suppose we have, for purposes of discussion, a recorded or live source of stereophonic sound material in the form of a mechanical magnetic tape, soundtrack or group of electrical signals. In particular, let us consider a 2-channel system employing loudspeakers on the left and right of an auditorium stage, as shown in Fig. 1. We combine the signals of the channels, delay them from 10 to 35 msec, and feed a central loudspeaker with this delayed composite signal, all in addition to the regular stereophonic system. The effect of the additional centrally located sound source is to increase the sound level in the auditorium without appreciably altering the spatial localization due to the binaural effect.

The reason that this is possible appears to be due to the so-called Haas effect. Haas[1] made studies of the intelligibility of speech with various time delays be-

A contribution submitted on March 21, 1955, by Bruce P. Bogert, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

tween the direct sound and an echo. When the delay between the direct source and the delayed (echo) source is small (1–30 msec), the apparent source is the direct one, and the delayed source does not appear to be operating, except in that it contributes to the total loudness. This effect is independent of the location of the sources, and the delayed source must be as much as 10 db more intense than the direct one before the delayed source is perceptible as such.

If the delay is greater than some critical value, the delayed source becomes obtrusive, and the effects described above disappear. The critical value ranges from 40 to 100 msec for speech, depending on a number of factors including the relative intensity and the frequency spectra of the direct and delayed sources.

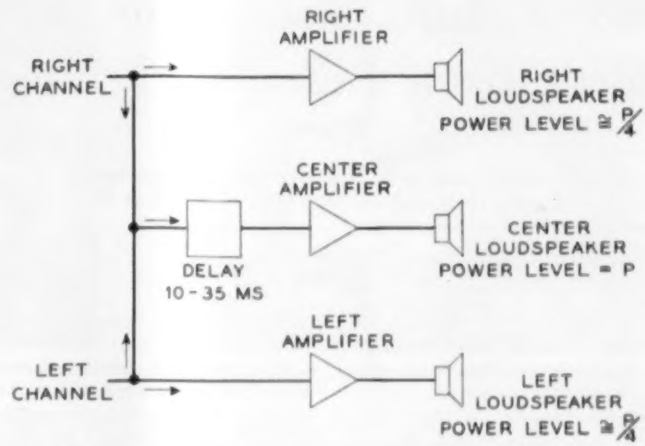


Fig. 1. Two-channel stereophonic reproducing system with additional delayed composite signal, centrally radiated to enhance the sound level.

A test was made of this method in the auditorium at the Murray Hill Laboratory. A binaural magnetic tape of classical orchestral music was used as a source.[2] The tape was reproduced on a dual-track magnetic tape recorder, and the two outputs were amplified and connected to the left and right loudspeakers behind the auditorium stage.

The two amplifier outputs were also connected to the conjugate arms of a hybrid, the output of which was sent into a recorder-reproducer machine that could be adjusted to operate at a tape speed of either 30 or 60 ips, providing a delay between the recorded and reproduced signal of either 69 or 34.5 msec, respectively. The frequency response was partially equalized for the 60-ips tape speed. The equalization for a tape speed of 60 ips was not particularly effective for the lower speed. The signal-to-noise ratio for the 60-ips tape speed was about 35 db.

The delayed output was fed into the power amplifier driving the center speaker in the auditorium. By varying the delay-unit reproduce gain, the power output of the center speaker could be adjusted from zero up to 15 or 20 db greater than the output of the left and right loudspeakers.

With the binaural program material, the relative levels were equalized from the left and right speakers, with the center one inoperative. Using a delay of 34.5 msec, the level of the center speaker was raised gradually until observers in the center of the auditorium could just notice the presence of sound emanating from the center speaker. The program source was then replaced by an oscillator feeding one of the binaural channels only. The difference between the sound levels of the center speaker and the other was measured, and it was found that the level of the center speaker was from 8 to 12 db higher than that of the left or right one. Further listening tests with more observers indicated that a program level in the center speaker 8 db above that in the left and right speaker was not noticed in the treble range, but the apparent position of the bass instruments seemed to move toward the center with a level difference greater than 5 db.

When the delay was changed to 69 msec from 34.5 msec., by a speed change in the delay unit from 60 ips to 30 ips, the stereophonic property of the system could no longer be observed. The sound appeared to come from the center speaker only, and the overall effect was that of a standard single-channel sound-reproducing system.

The lower relative levels of the left and right channels with respect to the center one could most easily be observed when the program material radiated from the center speaker was not the same as that radiated from the left and right ones. This could be done by using the delay unit as a tape reproducer, using material recorded from a previous selection. The center speaker output then seemed to be much louder than that of the binaural system, and would almost drown out the left and right speakers. By reverting to the "normal" operation as a delay mechanism, the center speaker's output became almost unnoticeable, even though its sound level was greater than the combined levels of the left and right speakers.

The greatest usefulness for this proposal would seem to be in motion-picture theaters, in which centrally located speaker systems of adequate power capacity already exist. To add a 2-channel stereophonic would mean adding two loudspeakers (right and left) of smaller power-handling capacity, and a method of delay for the signal to be radiated from the center loudspeaker. If, for example, the motion-picture film uses two soundtracks for the two channels, side by side, then a sound pickup unit could contain the two photocells for the right and left tracks, and a third photocell, which scanned both tracks, spaced sufficiently far behind the other two to provide the required delay. If a standard soundtrack were played, the third photocell would act as the regular sound pickup means, and the right and left speakers would not change the illusion that the sound was centrally located as in an ordinary system.

References

1. H. Haas, "Über den Einfluss eines Einfachechos auf die Hörsamkeit von Sprache," *Acustica*, *1*, No. 2, 49–58 (1951).
2. Audiosphere BN704/7.5, "7.5 ips binaural magnetic tape recording," Audiosphere, Inc., Livingston, N.J.

Motion-Picture Photography in Guided-Missile Research

By WILLIAM A. PRICE
and ERNEST H. EHLING

The use of motion-picture cameras for recording the flight of guided missiles is described, including the equipment and techniques involved and the accuracy limitations of the measurements obtained.

The performance of experimental guided missiles can be most effectively evaluated through use of the motion-picture type of instrumentation. At the Air Force Missile Test Center (AFMTC), Patrick Air Force Base, Florida, numerous types of cameras are utilized for this purpose, including several specially modified high-speed and normal-speed motion-picture cameras.

AFMTC fires missiles from the coast of Florida on a range extending through the British West Indies and terminating at Puerto Rico, as shown in Fig. 1. The range provides missile contractors with a long-range, instrumented proving ground on which new missile models and modifications to existing models may be tested (Fig. 2). Photograph instrumentation is located at the launching site, along the missile flight path and at the target area.

Both the qualitative and data type of records are obtained during test firings on the range. Documentary or historical footage is obtained by 16mm Bell & Howell and 35mm Mitchell cameras. Other Mitchell and Fastax high-speed cameras obtain time and motion studies of missile preflight and launching operations. Data on exhaust-flame temperatures and propagation are obtained at the launching site by these cameras, which are usually linked electronically to the missile's operating sequence.

Quantitative data are obtained through use of Bowen ribbon-frame (CZR-1), Clark ribbon-frame, AFMTC modified Hulcher 70mm cameras and Askania cinetheodolites. These record the momentary attitudes and momentary positions of the missile. Velocity data in the form of curves are obtained by breaking position data into $\frac{1}{4}$-sec increments, the computed distance being divided by the time increment. Acceleration data are similarly calculated from the velocity-time curve.

Accuracy of Measurement

Accuracy of measurement is of a relatively high order. The magnitude of the systematic angular accuracy of cameras in the CZR-1 (Bowen) class (where the camera consists of the image-recording device and necessary optics) is ± 15 sec of arc. If we now expand a little on the concept of the word "system," the mounting and orienting devices must also be included with the camera. Position data thus determined (and this is always the minimum system-limiting factor because the question "Where is the camera pointed?" must naturally be asked) now include the further accuracy limitations of these sighting and mounting systems. The magnitude of the systematic angular-error-for-position data now increases to ± 35 sec of arc. The concept of the word "system" must unfortunately still be enlarged upon to complete the final picture, and when we do so, we find such things appearing as to the use of target boards in lieu of the camera sighting and orientating devices, the accuracy limitations of the film readers, the influence of atmospheric conditions to include haze, heat abberations, etc., on the clarity of the image, the accuracy of the human element involved, pure mathematical accuracy limitations brought about by the method of data solution, the accuracy of survey data, etc. For the most part these factors are additive, unfortunately. At the AFMTC, therefore, the overall magnitude of the angular deviation on position data for fixed cameras is ± 2 min of arc.

The distances at which the fixed-camera stations are located from the proposed line of flight of the missile (2000 to 5000 ft) limit the magnitude of the random-position error of the space vehicle in reference to its origin to ± 3 ft. The magnitude of this error falls within the tolerances specified by the missile contractors.*

Fortunately, when it comes to the question of velocity-acceleration data, the accuracy limitations of fixed instrumentation change for the better. Now the orientation error of the mounting and sighting systems can be deleted, for the camera is pointed in the same position (fixed) for all missile positions. Velocity and acceleration data, as previously stated, are computed from relative changes in missile position, so the error between positions does not involve the error between any one position and the earth. The use of fixed-camera instrumentation to attain velocity-acceleration data therefore actually increases the precision of its measurement. Collectively, all sources of error contribution make the overall magnitude of the angular deviation for fixed cameras, where velocity-acceleration data are concerned, ± 1 min of arc. In terms of acceleration, this amounts to ± 0.75 *g*.

It must be remembered that information gained through instrumentation of this nature is based on the best statistical guess as to the actual path the missile did cover. If enough Bowen cameras were available, with the aid of FLAC (Florida

*Amy E. Griffin and Elmer E. Green, "Accuracy limitations on high-speed metric photography," *Jour. SMPTE*, *59:* 485–492, Dec. 1952.

Fig. 1. Air Force Missile Test Center, Florida Flight Test Range.

A contribution submitted on February 25, 1955, by William A. Price, RCA Service Co., Air Force Missile Test Center, Patrick Air Force Base, Cocoa, Fla., and Ernest H. Ehling, formerly of Technical Systems Laboratory AFMTC and presently with Sherman Fairchild & Associates, Inc., 30 Rockefeller Plaza, New York 20, N.Y.

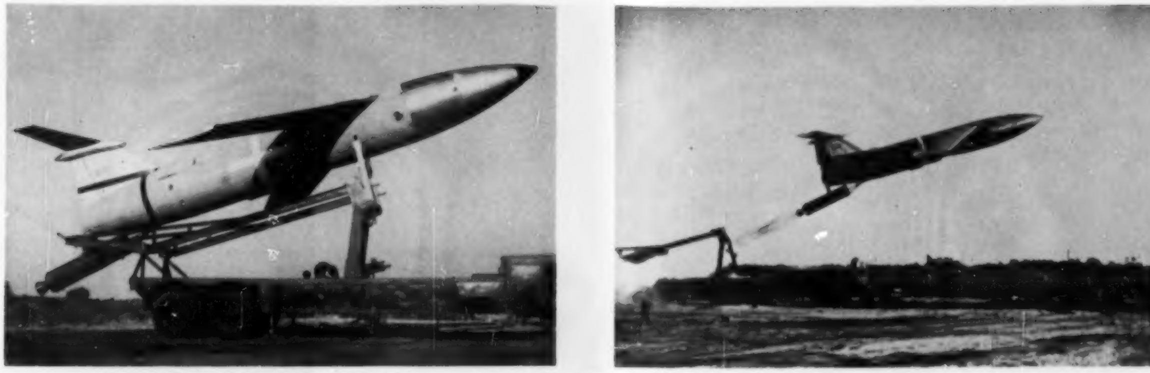


Fig. 2. B-61 Pilotless bomber (Matador) manufactured by Glenn L. Martin; Cape Canaveral Auxiliary Air Force Base.

Fig. 3. Attitude tracking camera, 120-in. focal length folded Newtonian.

Automatic Computer) the perpendicular distance between intersecting rays for each point of the missile's trajectory could be computed for a number of cameras. A frequency distribution curve could then be plotted over the range of these errors, and the standard angular deviation of the range instrumentation could be statistically determined.

In tracking optical instrumentation, two basic types of photographic equipment are employed. In order to determine some of the aerodynamic characteristics of missiles in flight, tracking Mitchells (with timing) are employed with long-focal-length lenses to determine changes in attitude (Fig. 3.).

The second class of tracking optics involves the well-known Askania cinetheodolite. This instrument is primarily used to determine position data. With the cinetheodolite, each frame records the absolute position of the missile in reference to the earth with a random angular deviation of about ± 30 sec of arc. However, at the AFMTC, the maximum random angular deviation of the cinetheodolite instrumentation (to include orientation targets, film readers, etc.) is found to be of the order of magnitude of $\pm 1\frac{1}{2}$ min of arc. A large portion of this error is due to the Center's location in the subtropic climate of Florida and the Caribbean Islands. The problems of thermal expansion, heat aberrations, etc.,

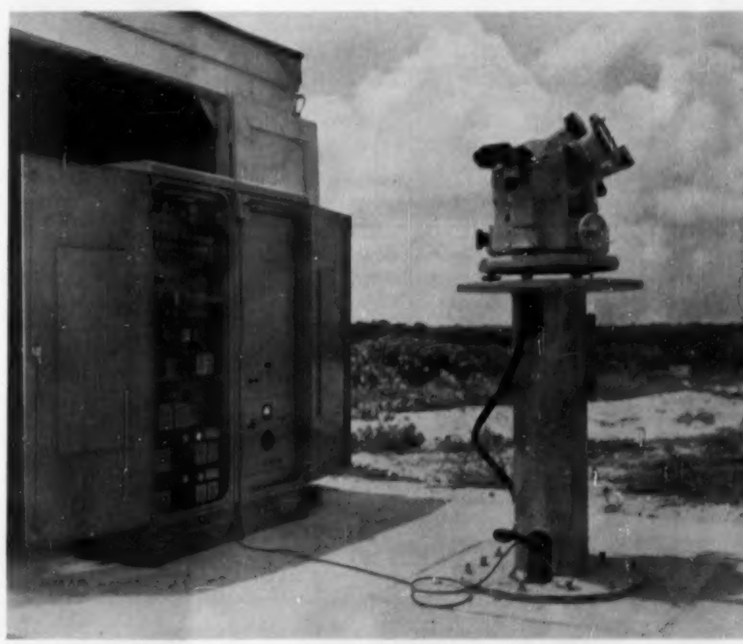


Fig. 4a. Askania Cinetheodolite, Model Gtk-40, Site 1.2; at left is the movable building and the timing rack.

Fig. 4b. Askania Cinetheodolite film, 84-in. focal lens.

Fig. 5a. Hulcher camera frames with timing.

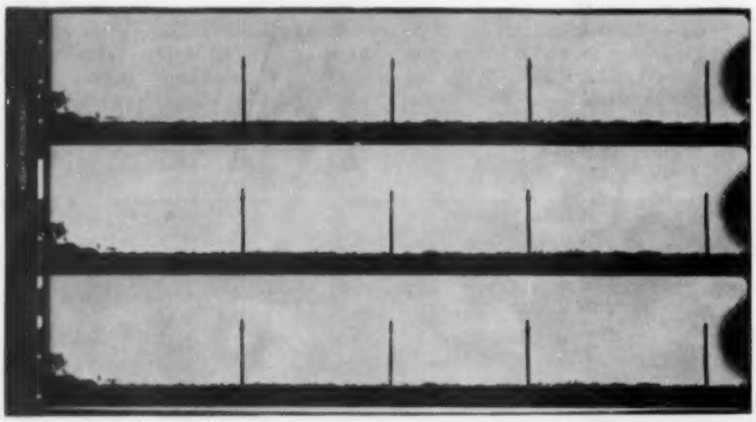


Fig. 5b. CZR-1 (Bowen) camera frames with timing.

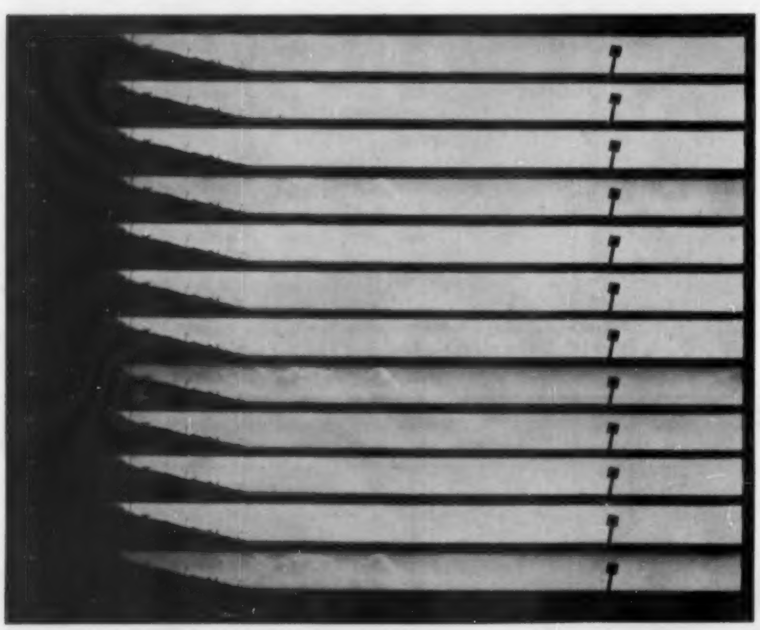


Fig. 5c. Clark camera frames with timing.

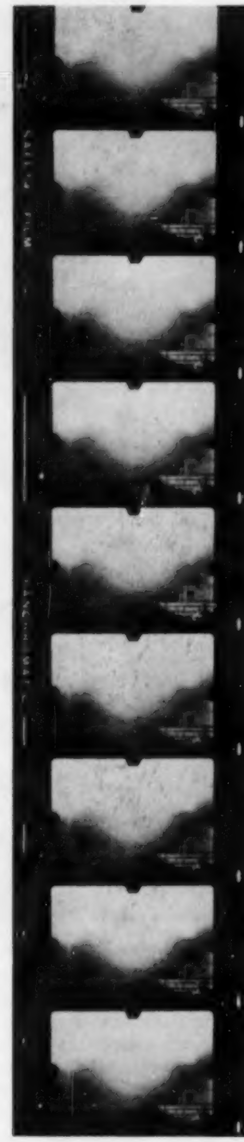


Fig. 5d. Time and motion study with timing.

with the cinetheodolites are of paramount importance and have led AFMTC into a program of studies of visibility, image shift due to thermal expansion, etc. The tolerances now obtainable have been sufficient to meet the contractor test requirements. A typical theodolite site and an example of theodolite film are shown in Figs. 4a and 4b, respectively.

Timing System

One principal requirement in the use of motion pictures for study of missile behavior is, as previously stated, the creation of a time record to refer each motion-picture frame back to zero time. All specially developed photographic instrumentation incorporates some type of timing system as a part of its develop-

ment, and the Mitchells, Fastaxes, and other standard cameras include AFMTC timing.

The timing signals are generated at a central control and transmitted to the camera sites as sine waves. The waves are 1000 and 100 cycles/sec generated to a tolerance of ± 1 μsec. In addition to these signals an identifying code burst is sent out each second. At each camera location an electronic Camera Terminal Timing Unit shapes the sine-wave signals into unidirectional spiked pulses and reshapes low-level code spiked pulses to square-wave pulses. They are superimposed on each other to pulse NE-2 or NE-51 bulbs in the camera timing projectors recording the time reference on the film (Figs. 5a–5d).

In a timing system where the time increment between pulses is of the order of milliseconds, a code signal becomes necessary to identify the time interval being measured, and to reference the time of missile firing operations. A binary code is most readily adaptable to a pulsing system, whereas decimal coding requires far more equipment to generate and record. In the binary code used, a reference mark always precedes a code burst. A complete absence of code for a second following the reference mark indicates zero time in the code. A code burst 10 msec after reference time indicates 1 sec. The absence of a burst at 10 msec and presence of one at 20 msec indicates 2 sec. The presence of a code burst at both 10 and 20 msec after the reference mark is the sum of the two, or a total of 3 sec. This progression continues, the value of the 10 msec bursts is 2^{n-1} and each second is identified by the sum of all values indicated by code bursts. Examples of second identification are shown in Fig. 6.

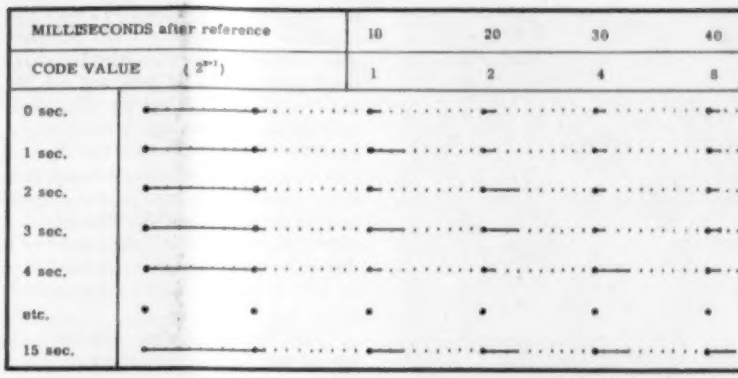


Fig. 6. Binary timing code, second identification.

The time code in nonintermittent-film-transport cameras is recorded at the center of the exposed picture area whenever practical so that the true time of picture may be read directly. In the intermittent-action camera the timing is recorded on the film at a point where film motion is constant. An example is the familiar Mitchell camera where timing is put on at the film drive sprocket.

The intermittent-action camera presents the problem of time correlation. It is necessary to correlate the time code from its displaced position to the shutter opening of the camera. This problem is solved by recording a pulse generated by the camera simultaneously with timing. A quarter-inch square-face alnico magnet is embedded in the camera flywheel and a coil is mounted so that for each revolution of the flywheel a single spiked wave is generated. The spiked wave is sent to a pip amplifier which amplifies and returns the signal to the camera to pulse the NE time-correlation lamp. The NE lamp is adjusted to fire at mid-open shutter exposure. The time interval between indicated time and actual exposure time is then determined as a function of film-path length and pip location (Fig. 5a).

Equipment

The following photographic equipment is used extensively throughout the range.

The K-24 intermittent-action camera is used close to the missile on launching for documentary coverage. The camera holds sufficient roll film to take 125 exposures (5×5 in.) at the maximum rate of 3 photographs/sec. The camera consists of a magazine, gearbox (with focal plane shutter), camera body and lens. The lens most commonly used is an Aero Ektar 7-in. $f/2.5$ lens. The K-24 is operated from a 24-v d-c source. The field coverage is fixed (a function of lens angular coverage, frame size and offset distance) and exposure times are synchronized with the missile sequence to record launching events chronologically.

The Fastax 35mm nonintermittent camera is used only at the site of missile launching and is operated normally at 600 frames/sec, although rates up to 3500 frames/sec are practical. In this camera, the film capacity with present models is limited to 100-ft reels. Operation is automatically started by relays synchronized with missile launching events, and the total running time is less than 5 sec. Two separate motors are used, one driving the film-transport sprocket and the other actuating the take-up magazine spindle. Modification of this camera by the Air Force Missile Testing

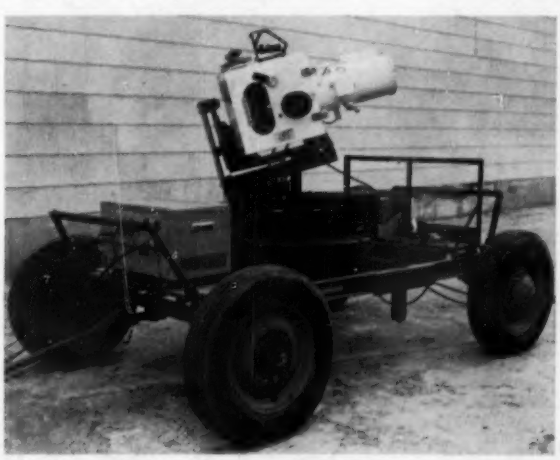


Fig. 7. CZR-1 Bowen camera and mount (AFMTC modified 60-in. searchlight trailer).

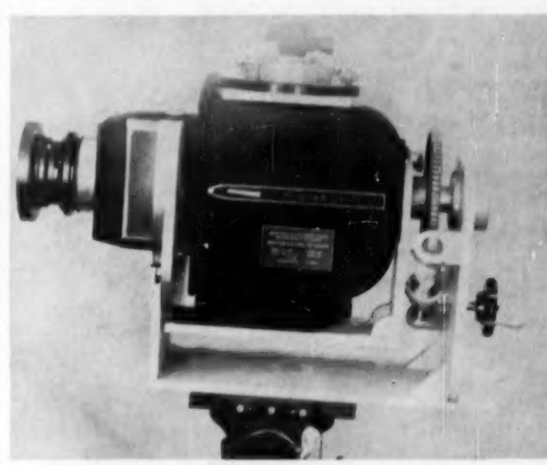


Fig. 8. Modified Hulcher 70 Camera with roll-mount adapter, binary code timing.

Fig. 9. Clark Ribbon Frame Camera, binary code timing.

Center consists of replacing the Fastax timing projector with one capable of recording AFMTC timing signals using an NE-51 neon lamp.

The CZR-1 (Bowen) camera film travels at a constant rate of speed and is classified as a ribbon-frame camera. At AFMTC the camera normally uses standard $5\frac{1}{2}$-in. × 56-ft. aerial film. The maximum capacity of the camera magazine is 100 ft. At present these cameras are used only in the launching area 5000 ft to the rear of the missile pad and 2000 or 3000 ft to the side and down the flight line from the missile. The normal frame rate is 30 frames/sec, yielding 1- × 5-in. frame formats. The cameras are aimed to photograph the anticipated trajectory path of the missile. Camera operation is remote and is synchronized with missile launching to obtain required data.

The camera consists of a body containing a shutter drum driven by a 3-phase synchronous motor. An inner housing contains a film drum and film magazine compartment with necessary gear for transporting film. The film-drive single-phase motor is mounted on the camera door and drives the film-transport mechanism through a clutch operated by 28 v, d-c, when the door is closed on the camera body. A lens mount is attached to the front of the camera body and contains a 10-in. Tessar lens, a reflex viewer, 3 fiducial projectors and a dial indicator calibrated in thousandths of an inch to indicate the focusing position of the lens (Fig. 7).

The Hulcher 70mm cameras are among our latest additions to our fixed instrumentation. The frame rates vary from 0 to 25 frames/sec with frame format dimensions of $2\frac{1}{4}$ × 5 in. One-hundred-foot rolls of 70mm linagraph shellburst film are used. The cameras have been extensively modified in that fiducial marks, timing projectors, sighting scopes and mounts have been added. The gear trains have been reworked, substituting some phenolic gears in place of metal ones, and the pressure plate and film path have been changed to secure more accurate registration of the film in the focal plane (Fig. 8).

The Clark Ribbon Frame Camera film-transport mechanism is nonintermittent, and standard $5\frac{1}{2}$-in. × 56-ft. aerial film is used. These cameras are used from 2000 to 5000 ft from the missile, usually one to the rear of missile on the launching pad and the second for side coverage. The frame size is $\frac{5}{16}$ × 5 in. and normally operates at 50 frames/sec. This frame size necessarily means that the camera must be accurately oriented in respect to the anticipated missile trajectory. It is pre-aimed and operated by automatic controls synchronized with missile events. The camera uses a standard 7-in. Aero Ektar lens with four optical flats to move the image at the same rate as the film speed. The two $\frac{1}{35}$-hp Bodine motors (one used to drive the shutter, the second to drive the film) are split-phase induction motors with their windings parallel to ensure synchronization. In operation, the motors are started prior to missile launching to drive the shutter and film-transport gear train. Actual film motion does not occur until a clutch is energized. The clutch drives the film at a constant speed through metering rolls; the take-up spool overdrives and slippage is permitted by a cork clutch facing on the take-up spool to allow for change in film diameter (Fig. 9).

Three types of cinetheodolites are in use at AFMTC, two German Askania models and the Scophony-Baird theodolites manufactured in England. The film-transport action is intermittent, advanced by pulsing rates of 1, 2 or 4 frames/sec. Linagraph shellburst 35mm film is used in the magazines in 100-ft lengths. These cameras are tracked manually with automatic pulsing regulated from one master control station. Elevation and azimuth scales are two etched-glass circles calibrated for 360° in $\frac{1}{2}$ min of arc with verniers reading to minutes; post-data interpolation to $\frac{1}{10}$ of a minute. Segments of the scales are photographed simultaneously with the image through optical trains and SA 309 flashlamps, at the instant the shutter attains maximum open position. The lenses used vary from 60-cm focal length, refraction type, to 84-in. folded Newtonian. Some of the modifications to these instruments are: utilization of long-focal-length lens systems with necessary counterbalancing, SA 309 flashlamp system to replace mechanical shutter system in data presentation and open-aperture plates in lieu of glass reticules in the film plane.

As missiles go farther and faster, the problems of obtaining data by photographic means become increasingly complex. The cameras used and problems solved by the Air Force in the field of missile testing should prove of value in the future not only to other facets of Air Force work but to industry as well.

Single-System Printing Device for Bell & Howell Model J Printer

By ROBERT G. VANCE

The Bell & Howell Model "J" printer has been adapted to permit the printing of single-system picture and soundtrack simultaneously, at the same aperture, from the regular single light source, yet allowing conventional light changes without causing variations in soundtrack exposure.

With the coming of television, 16mm film has acquired a new role, that of television newsreel. Unlike its big brother, 35mm theater newsreel, which is released once a week, television news is a daily affair — in fact, hourly.

Our laboratory, being located in Washington, D.C., assumes the tense atmosphere of a busy daily newspaper pressroom as the many newsreel prints are rushed through in time to be put on planes and delivered to stations all over the country.

These new requirements placed on 16mm film have made it necessary to seek new techniques in the faster printing and processing of film.

One of the problems that gave us some concern was printing of the single-system negative. First, loop trees were constructed that would accommodate loops of up to 250 ft. These worked very nicely but a second run still was required to expose the track. To eliminate the second run, the answer to this was, of course, to print picture and sound simultaneously. This meant either adding another head for the track or introducing an additional constant light source at the same printing aperture in such a manner that neither light would interfere with the other.

Presented on April 21, 1955, at the Society's Convention at Chicago by Robert G. Vance, Byron, Inc., 1226 Wisconsin Ave., Washington 7, D.C.
(This paper was received on March 17, 1955.)

In 1852 a patent search was made which, to our surprise, revealed many devices using both of these methods. Some of these dated back to the early days of sound motion pictures. It was our opinion that any similar device would be a direct infringement. We therefore decided to build one of an entirely different design that would not infringe on the patent rights of existing devices, and adapt it to the Bell & Howell Model "J" Printer. Since there was already a constant light source in the regular printing light, we decided to utilize some of this light. To do this would require by-passing the rays of light past the light-change shutter and into the soundtrack area of the printing aperture.

In our first adaptation in 1952, in order to bypass the light-change shutter, a ½-in. hole was drilled through the bottom of the lamp housing and a second hole in the very bottom of the light-change shutter housing. A piece of clear Plexiglas rod was bent into a curve to connect these two holes. A similar piece of the plastic rod was tapered down and the end shaped to fit into the printing aperture in the soundtrack area. This second piece was attached to a small shaft which was brought out of the top of the shutter housing, and a knurled knob on the end permitted it to be swung in or out of position. Thus the light was literally piped into the soundtrack area of the film.

Actual film tests indicated that the loss in the high frequencies due to diffusion in the plastic material was not great, so the printer was put into service. About two or three weeks later, however, we noticed a great loss in high frequencies apparently due to physical changes in the plastic. To remedy this situation, the second plastic tube was replaced by a concave reflector, so arranged that it picked up the light from the end of the first plastic tube and concentrated the rays into the soundtrack area. So that the light from the picture area would not reach the track area and vice versa, a thin metal partition was inserted in the printing aperture and extended back to the reflector, which was attached to the same vertical shaft that originally supported the second plastic tube. This allowed the unit to be swung in and out as necessary. This revision was successful and more than doubled the amount of film that could be printed in a given time.

In 1954 we decided to install a radical modification of our device that we had designed in the interim.

Since there is always one constant amount of light in the shutter housing, namely the portion of the diffusion glass that the shutter does not cover on the lowest light, or light No. 1, we decided to use a portion of this light and reflect it into the soundtrack area of the printing aperture, using two concave dental mirrors. After we had experimented with several mirrors, two were found to have the proper curvature to concentrate the rays of light No. 1 into the track area. The first mirror was placed just above the printing aperture and the second beside the diffusion glass and slightly above it. (Fig. 1). To prevent more illumination than light No. 1 from reaching the first mirror, a flat vane or partition was placed in such a horizontal position that only the rays of light No. 1 could reach it.

In this modified device, as in the original one, a vertical vane extends into the printing aperture and separates the picture and soundtrack areas. With both

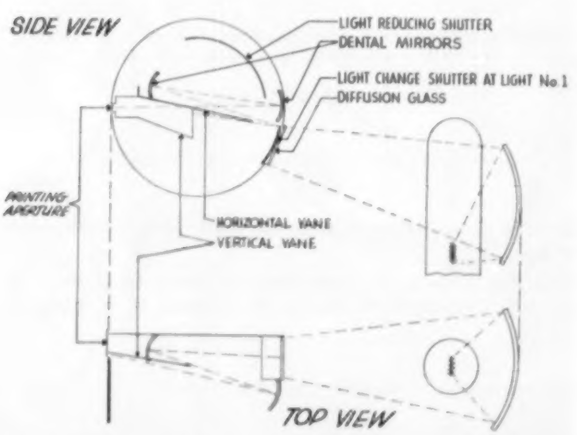


Fig. 1. Placement of mirrors to reflect light into soundtrack area.

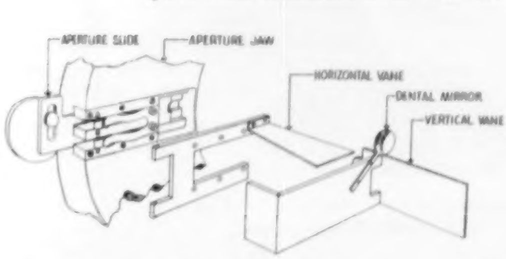


Fig. 2. Support of mechanism by bracket attached to aperture jaw.

vanes in position, the picture area was covered with black tape so that we could read the illumination in the soundtrack area with a foot-candle meter. It was found to be more than adequate for normal track exposure, and a third vane or shutter was therefore added at the top of the housing to decrease the amount of light as needed. It is raised or lowered by an adjusting screw protruding from the top of the housing.

The entire mechanism except the second mirror is supported by a bracket attached to the aperture jaw (Fig. 2). The vertical vane and first mirror are attached to an L-shaped arm that is hinged to the bracket and is swung in and out of position by the aperture slide pressing against it while the horizontal vane remains stationary. Merely flipping the aperture selector from sound or picture only to full aperture automatically brings the single-system device into position.

This device, along with loop printing and a printer speed of 120 fpm, has made it possible to turn out many prints in very few minutes and yet leaves the printer available for conventional release printing.

Discussion

George Lewin (Signal Corps Pictorial Center): It was not clear whether you have a means for easily adjusting the light.

Mr. Vance: The light is adjusted by the flat curved vane which is at the top by a screw pressing down against it. It acts like a flat spring.

Mr. Lewin: You use that as a means of adjusting when you want to change from one soundtrack density to another?

Mr. Vance: Once adjustment is made, the variations are usually taken care of by the setting of the amperage on the printing light itself.

Mr. Lewin: But changing the amperage in the printing light would change your picture exposure also.

Mr. Vance: True. We found that once it is set up for newsreel printing it very seldom has to be readjusted.

Mr. Lewin: I can recall a couple of years ago there was published a description of a modification which allowed you to print sound and picture simultaneously that used a separate light. Is that one of the systems you were referring to? [*Jour. SMPTE, 61:* 512–515, Oct. 1953]

Mr. Vance: Yes.

Anon: Yes, you could calibrate that light and use it as a timing device to accommodate different densities of the soundtrack.

Arthur Rescher (Capital Film Labs): In the same vein as the preceding remark, I would like to state that Capital Film Labs has a two-light printing device in service since, I believe, 1952 for the printing of newsreel films.

Errata

E. I. Sponable, H. E. Bragg and L. D. Grignon, "Design considerations of CinemaScope film," *Jour. SMPTE, 63:* 1–4, July 1954.

Page 2, in the table which is part of Fig. 1, two of the metric equivalents should be corrected:

For: D . . . 1.86 ± 0.01
read: D . . . 1.854 ± 0.01
For: I . . . 26.63 ± 0.05
read: I . . . 26.64 ± 0.05

Glenn E. Matthews and Raife G. Tarkington, "Early history of amateur motion pictures," *Jour. SMPTE, 64:* 105–116, Mar. 1955.

Page 110, col. 2, para. 3, 16th and 17th lines:

For: ". . . the Amateur Cinema League which was founded in 1927."
read: ". . . the Amateur Cinema League which was founded in 1926."

(It may now be noted that the Amateur Cinema League was absorbed by the Photographic Society of America in December 1954.)

Page 113, Fig. 14: The caption about examples of Pathex Films should be augmented by the information: "(twice original size)."

Page 114, the caption for Fig. 17a:

For: "Diagram of Kodak lenticular film (1928.)"
read: "Diagram of Kodacolor lenticular film (1928.)"

In the April 1955 *Journal*, p. 196:
OFFICERS AND MANAGERS OF SECTIONS

An out-of-date roster was presented for the Central Section as far as some of the Managers were concerned. The following complete Section listing contains one change in Managers made since April.

CENTRAL: Chairman, J. L. Wassell; *Secretary-Treasurer*, K. M. Mason; *Past Chairman*, C. E. Heppberger; *Membership Chairman*, H. W. Lange; *Program Chairman*, P. E. Smith; *Managers:* H. H. Brauer, J. C. Diebold, R. G. Herbst, M. Goldstein, D. W. Ridgway, H. Ushijima.

Sound-Effects Track Noise-Suppressor

By JOHN F. BYRD

A simplified noise-suppressor for the effects track in CinemaScope reproduction operates in the speaker line, thus using the full gain of the system, and uses two tuned circuits: one accepts and rectifies the 12-kc control tone to operate a speaker relay, and the other rejects the 12-kc tone from the wanted program material in effects speakers. The unit uses no tubes or power supply.

In CinemaScope sound reproduction four magnetic tracks are recorded on the film. The fourth, or effects, track is much narrower than the other three main program tracks and requires considerably more system amplification for satisfactory sound level from the effects speakers than that required for the stage speakers. During periods when there is no effects program material, this additional amount of gain generates too much noise in the effects speakers, and a device is required to either reduce this gain or disconnect these speakers. When the effects program material is to be reproduced, a 12-kc control tone is recorded on this fourth track, approximately 18 db below 100% modulation. This tone is utilized in various noise-suppressor circuits for keying on or off the effects channel.

Location of Suppressor in System

This simplified noise-suppressor works in a 250-ohm line from the power amplifier to the effects speakers. All the available gain of the fourth channel is used to amplify the control signal; and by virtue of the fact that the amplifier must simultaneously reproduce the 12-kc control tone and program, the total amount of power available for reproducing the program material is approximately 98% of the rated output of the power amplifier. The 2% of power used in reproducing the control tone is negligible for all practical purposes.

Presented on April 18, 1955, at the Society's Convention at Chicago by John F. Byrd, Theatre Sound Engineering Group, Bldg. 10-4, Radio Corp. of America, Camden 2, N. J.
(This paper was received on March 11, 1955.)

Technical Description of Circuit

Figure 1 shows the circuit of this suppressor. It consists essentially of two tuned circuits and a relay. The 12-kc acceptor circuit is a series-tuned circuit consisting of C-1, C-2, and L-1. At resonance the 12-kc control voltage is built up across L-1, rectified and then used to energize the relay coil, which in turn closes and connects the effects speakers to the output of the power amplifier. This same action of the relay removes the resistor R-1, which is used to load the output of the power amplifier when the effects speakers are disconnected. A minimum of 0.75 v of 12-kc signal impressed across the input of the unit will reliably close the relay. Since the effects speakers are normally less sensitive than the stage speakers, the average power necessary for proper sound level in the effects speakers is usually several watts. This would, in practice, increase the 0.75-v minimum sensitivity to several volts. Since this control signal remains constant with varying recorded program levels, a large sensitivity safety factor is assured for operation of the relay.

The 12-kc rejector circuit is a modified T-section low-pass filter consisting of L-2, L-3, C-3, C-4 and C-5. The filter "cuts off" sharply after 8000 cycles and is down a minimum of 35 db at 11 kc. Thus the 12-kc control signal is attenuated to inaudibility, while the useful program material passes through to the effects speakers.

Operation and Controls

Simplified "field" adjustment and emergency operation are incorporated in the unit. There is only one adjustment (C-2), which varies the tuning point of the acceptor circuit for maximum sensitivity and allows for slight variations of component constants and projector motor speed. For optimum performance, a 12-kc magnetic film test loop should be run in the projector, and the d-c voltage, measured across the relay coil, should be increased to a maximum by adjustment of C-2. An emergency switch provides for by-passing the relay and most of the components in the acceptor circuit. The low-pass filter remains in the circuit to attenuate the objectionable 12-kc control signal from the program material reproduced in the effects speakers. No adjustment is necessary in the rejector circuit, since the low-pass filter attenuates sufficiently at 11 kc and this would allow for normal variations in the 12-kc control signal.

Conclusions

Figure 2 shows the noise-suppressor. It is small, has no tubes, requires no power supply, may be mounted anywhere in the effects speaker line, has only one "field" adjustment and is relatively inexpensive.

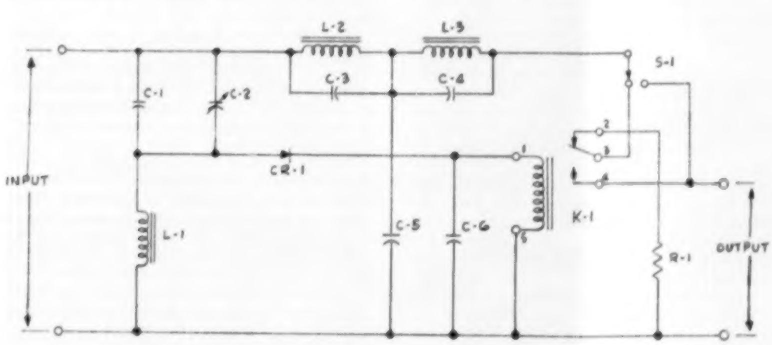


Fig. 1. Schematic diagram of noise-suppressor.

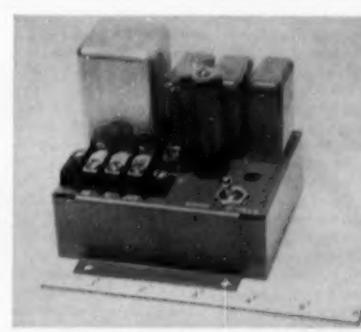


Fig. 2. Noise-suppressor for CinemaScope sound reproduction.

Perceptibility of Flutter in Speech and Music

By FRANK A. COMERCI

The following discussion was not transcribed and circulated in time to permit its publication with the article which appeared earlier in this Volume of the Journal, in March, pp. 117–122.

Discussion

Dr. John G. Frayne (Westrex Corp.): Did I hear you say that 0.25% is the minimum flutter perceptibility at five cycles?

Mr. Comerci: At five cycles about 0.4% was found in program.

Dr. Frayne: Now that seems absurd to me because in modern equipment we are designing for about one tenth of that.

Mr. Comerci: This does seem absurd, Dr. Frayne. However, I would like to repeat that in the experiments I was not interested in the absolute threshold, I was more interested in the relative threshold at various flutter rates. Now, the way I explained this was that we had an inherent flutter of about 0.2% in the flutter generator which probably produced a masking or hid the lower percent flutter amplitudes under investigation. I feel that if I had a system which would give us an inherent flutter as low as 0.05% that the threshold figures might agree with the absolute threshold found for tones.

William B. Snow (Consulting Engineer): Did I understand you correctly that all of these tests were made using headphones?

Mr. Comerci: Some were made using headphones, others were made using loudspeakers. Some of these tests were made using headphones directly and then introducing a reverberation chamber by putting a loudspeaker and a microphone in a reverberant chamber.

Mr. Snow: However, in that case you still used headphones?

Mr. Comerci: We still listened with headphones when reverberation was introduced by the chamber method.

Mr. Snow: And the two headphones were just in parallel on the same channel and each ear received the identical signal?

Mr. Comerci: Each ear received the identical signal, yes.

Mr. Snow: So there is a definite difference between that, as you pointed out, and the original tests in the reverberant auditorium where the two ears are receiving different signals in the true binaural sense? Or am I putting words in your mouth?

Mr. Comerci: No, that is correct.

Mr. Snow: There was a definite difference in the perceptibility as you pointed out. I just wanted to be sure in my own mind that I understood the conditions of your experiment and to see if I could figure out from my own experience why it did make a 10 to 1 difference in perceptibility.

Mr. Comerci: I don't find nor do I try to say that absolute perceptibility thresholds for earphone and live auditorium listening are the same. I merely said that the data obtained show that if one machine sounds bad in a soft room, it will sound bad in a hard room. If one machine sounds worse than another in a soft room it will also sound worse than another in a hard room. Now, as far as using the echo chamber I figure that the only reason flutter might sound worse in auditoriums than it does with earphone listening is, first, that you might get an amplitude variation because of your standing wave effects in the room. Now, these amplitude variations would exist with microphone and loudspeaker as well. The other thing that might exist is that the reflected wave might be of different frequency from the direct wave and that too exists when you have just a loudspeaker and a microphone. Now, there may be some binaural or stereophonic effects here but judging from what we know about the theory of hearing, I don't think that these will show up.

Mr. Snow: Well, on that line, as you pointed out, the curves were taken in the old Bell Laboratories auditorium which was a very, very live room for its size; I know it well. They did get increasing sensitivities at high frequencies. And that is the point where there is quite a difference at the two ears in a standing wave field. Even when you put the reverberation in as you did in the reverberation chamber with two headphones you would not get that effect. So I feel that might be one reason for a difference in the shapes of those curves.

Col. Richard H. Ranger (Rangertone, Inc.): Have you listened for fairly high flutter rates? I think that is one of the most important things that comes about due to vibration of the tape over the head.

Mr. Comerci: Unfortunately I didn't investigate flutter rates above 100 cycles per second. I got to the point where I found that its effect on tone was about the same as it was on music and I thought that there was not much sense in going to a higher flutter rate when Dr. Schecter has investigated higher rates. He has measurements for a single tone using flutter rates up to a thousand cycles. It is a shame that he does not publish his very interesting work.

Col. Ranger: What I mean is that clarity is definitely affected by these higher flutter rates and I feel that we should be more conscious of them.

Mr. Comerci: Well, I understand that a good deal of the modulation noise that we talk about in tape recording is actually high-frequency flutter and it would be desirable to measure the higher flutter rates. However, the measurement would become very difficult or impractical. I don't see too much reason for it. As we go higher and higher in flutter rate we already see that flutter is getting less perceptible.

Col. Ranger: It gets less perceptible as flutter, but it certainly does not get less perceptible as far as quality is concerned.

Mr. Comerci: But then wouldn't an I.M. distortion measurement show that? As soon as the rate of frequency modulation becomes high enough you start getting sidebands and those sidebands I think appear in an intermodulation measurement and probably would appear even if you only had a one-cycle modulation.

Col. Ranger: It would appear on I.M., if your I.M. measurements were such that they would note such things, but I don't think it would appear normally on an I.M. machine. Just as you suggested if there is a definite FM effect of this high-frequency flutter, if you change the frequency, you'll change the band of this ground noise or whatever you want to call it. And it would be more a case of very careful bandwidth measurement.

Mr. Comerci: Now let us say for instance that you thought there was a flutter rate of 100 cycles per second in your equipment, if you were to put a 1000-cycle signal into your equipment and play it back, then you would get the 1000 cycle and you would get 900 and 1100, 800 and 1200, etc., sideband frequencies. I'm not too sure, but I think they will appear in a distortion meter or a wave analyzer. I can't think of any flutter meter that would permit measurement of flutter rates as high as 1000 cycles when the low frequency is limited to 3000 cycles per second tone.

Col. Ranger: You are quite right that you have to get organized to note those things. For instance, a panoramic receiver would perhaps show it.

Edward S. Seeley (Altec Service Corp.): If I understood correctly your reference to intermodulation, I would not believe that flutter would show up in I.M. measurement. There is a distinct difference between amplitude modulation and frequency modulation. Under some conditions the sideband structures of both are very much alike as to amplitude; however, the phases between components are different in the two cases, and when these components are added up in the case of FM the resultant includes no variation of amplitude. Unless there is some frequency-discriminating device introduced into the circuit, pure FM will produce no amplitude modulation measurement.

Author's Comments

The discussion and comments following the presentation of this paper indicated that clarification is required to overcome certain misunderstandings as to the interpretation of the results.

Most of the difficulty seemed to arise from trying to compare the thresholds reported for these experiments to the "absolute" thresholds reported by others for pure tones. In previous experiments there was essentially no inherent flutter in the flutter generating instruments. In these experiments, I could not think of any way to electronically or otherwise simulate flutter in program without having an inherent flutter in the generator. It might have been possible to design a flutter generator with less inherent flutter than those I had used, but I felt the time would have been better devoted to the actual experiments. Besides, I was primarily interested in determining whether the effect of flutter on program was similar to its effect on a single 1000-cycle per second tone. As such, I was not concerned with the absolute thresholds, which probably will never be approached in actual reproducing equipment. Perhaps, if I had used the terminology "Masked Flutter Thresholds" in Figs. 5 through 10, I might have been better understood.

Many appeared to be disturbed when they saw curves which they understood to indicate that flutter of less than 0.25% rms amplitude would not be detected by a listener in program. This has not been shown, nor do I believe it to be the case. I merely say that the listeners used in the experiments on the average sensed no degradation in program quality when flutter less than that indicated by the curves was introduced in program which already had about 0.2% rms flutter at a flutter rate of about 4 cycles per second. To the contrary, the inherent flutter in the flutter generator was easily detected by trained ears especially when listening to a loudspeaker in a live room.

The experiments show that the effect of flutter on program should be predictable from its effect on tone. They show that listener preference rankings were similar for various musical programs and a 1000-cycle tone for either earphone or loudspeaker listening or if reverberation were artificially introduced. There is evidence, not supported by data, that the absolute threshold shifts depending on the type of musical instrument heard and on mode of listening but the shape of curve for flutter effect vs. flutter rate is the same for a 1000-cycle tone, a chord, and piano and orchestra program. There is also evidence that the shape of the curve is maintained from earphone to loudspeaker listening. All of these results tend to justify the use of a flutter-weighting Index in a flutter meter but do not provide any indication of tolerable flutter limits.

It has been discovered that an error exists in the calculated threshold curve in Fig. 12. The correct curve should be that having threshold figures of 357, 230, 167 and 125% at pulse durations of 10, 25, 50 and 100 msec, respectively. The use of an rms meter is still indicated.

A Continuous Projector for Television

By OTTO WITTEL

A 16mm continuous projector designed especially for color television is described. It has an $f/1.6$ optical system and an optical compensator consisting of two semi-circular rotating and tilting mirrors. They are located in parallel light between an objective focused on the film and a collimating lens focused on a flying-spot scanner.

A GOOD CONTINUOUS projector is quite suitable for color television. For this purpose, it is not necessary to have the image framed by the projector, but the image must be continuously and uniformly illuminated at a constant level. Furthermore, the projector should pass a maximum of the small quantity of light available.

These requirements can be met by the use of a flying-spot scanner and an optical system that allows the full cone of light from the flying spot to reach the photocells at all times. Because the small amount of light requires a large-aperture optical system, the Eastman 16mm Continuous Television Projector was designed to accommodate an $f/1.6$ aperture.

Figure 1 is a general view of the projector proper, without the flying-spot scanner and the photoelectric-cell unit.

Figure 2 shows the complete optical system of the projector and the adjacent scanning and photoelectric-cell sections. The part of the system in the projector consists of a collimator, which has a focal length of 25 in. and is focused on the raster of the scanning tube in the separate flying-spot scanner; two tilting compensating mirrors to follow the motion of the film; a 3-in. $f/1.6$ objective focused on the film; and collecting lenses and a mirror to direct the light from the flying spot to two dichroic beam splitters. These beam splitters, which are in the photoelectric-cell unit adjacent to the projector, divide the light and direct it through correcting filters to red, green and blue photoelectric cells, where it terminates in three stationary spots about one inch in diameter.

Figure 3 shows a front and a reflected rear view of the assembly containing the compensating mirrors. It includes two semicircular mirrors, which are located between the collimator and the objective at an angle of 45°. Because the reflecting surfaces are in parallel light, it is not essential that they be in exactly the same plane. Each mirror is rigidly cemented to a flanged bushing mounted on the end of a shaft that can be adjusted to make the reflecting surface run true with respect to the bearings in which the shaft rotates.* Both shafts rotate and tilt in universal ball bearings, which have spherical inner and outer races and are located adjacent to the mirrors. Figure 3 shows also that the two mirror shafts extend in opposite directions from the reflecting surfaces of the mirrors. One mirror is driven by a cog belt from the camshaft. Between this mirror and the other, there is a flexible driving connection that allows the two to tilt independently while they are rotating.

Figure 4 shows the mechanism that controls the mirrors. On the outer end of each shaft, there are three ball bearings. To establish the lateral steadiness of the image, the middle bearings roll on adjustable rails. Each of the inner bearings carries a spring that holds its shaft against its rail. From the outer bearings, connecting links lead to the outer ends of a pair of rocker arms. These outer sections of the rocker arms can be adjusted to vary the ratio at which the arms operate. At the other ends of the rocker arms, there are spring-loaded rollers that run on opposite sides of a single control cam.

This cam tilts the mirrors so that they take turns in making the image of the raster follow successive pictures down through the gate. For a film speed of 24 frames/sec., the cam and mirrors rotate at 720 rpm. After rising uniformly through 270°, the surface of the cam returns in 90°. During these 90°, the mirror that is out of the light beam tilts back to its original position. Because of the large $f/1.6$ aperture of the lens and the 6-in. diameter of the mirrors, the change-over period from one mirror to the other is about half the time devoted to each frame of film. This change-over period is shorter for smaller lens openings.

Figure 5 shows the direction of rotation and tilt of the mirrors during the change-over period. The circular arrows indicate the direction of rotation as viewed from behind the mirrors. With a 3-in.

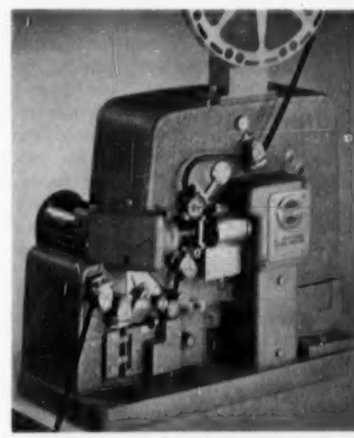


Fig. 1. General view of the projector alone.

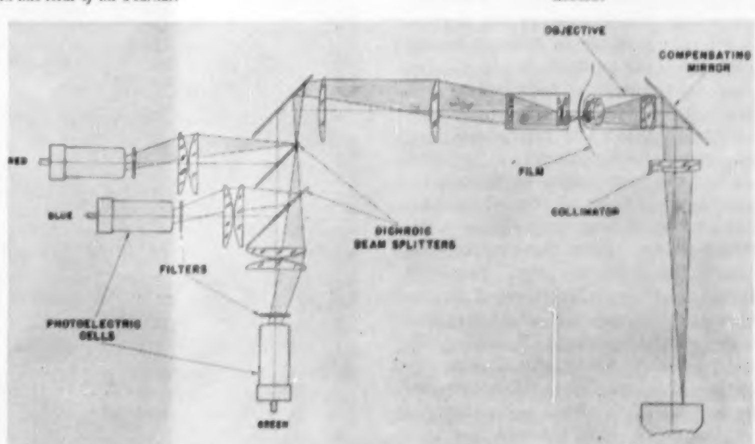


Fig. 2. Optical system of the projector and its associated equipment.

* Otto Wittel and Donald G. Haefele, "Continuous-projector problems," *the succeeding paper in this issue of the Journal.*

Presented on May 7, 1954, at the Society's Convention at Washington, D.C., by Otto Wittel, Camera Works, Eastman Kodak Co., 333 State St., Rochester 4, N.Y.
(This paper was received on March 7, 1955.)

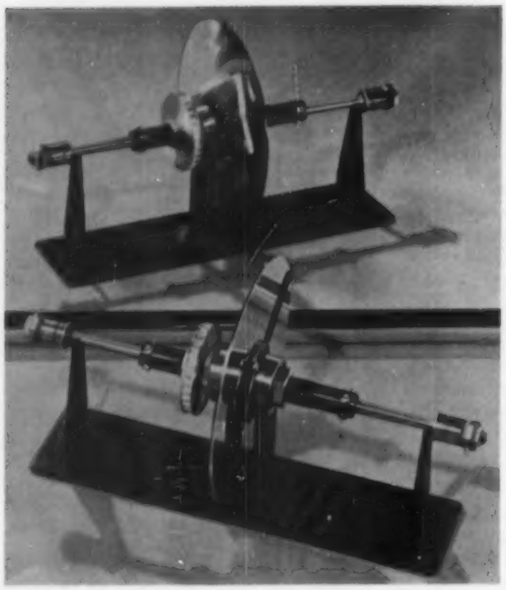


Fig. 3. Front and reflected rear views of the compensating mirrors.

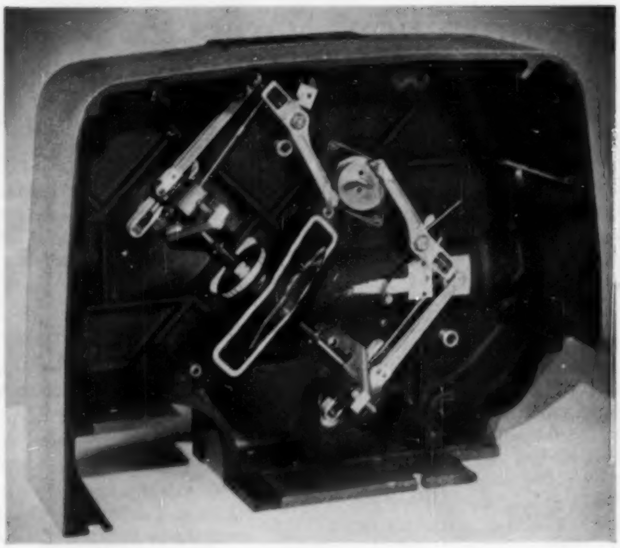


Fig. 4. Driving mechanism for the mirrors.

objective, the total tilt of each mirror during the 270° of its following action amounts to 4° 18′. As explained below, it is fortunate that the angle between the reflecting surfaces is less than 180° during the change-over period. With this arrangement, the incoming mirror sees the entering frame of the film, and the outgoing mirror sees the leaving frame. Under these conditions, each mirror would normally utilize more than half the objective, as shown in view A of Fig. 5. But view B shows that it has been possible to correct for the resulting temporary excess of light by the insertion of a narrow shutter that extends from the gap between the mirrors. Since this shutter shades the edges of the mirrors, it is not necessary to establish the width of the gap between them very accurately, and the gap can even vary somewhat during rotation provided the edges of the mirrors stay within the shadow of the shutter. This is not possible in systems having mirrors that tilt as shown in view C, because each mirror already utilizes less than half the objective.

Figure 6 shows the mechanism that compensates for variations in the average pitch of the perforations in the successive lengths of film. A control sprocket is geared to the mirror-tilting cam described above. From this sprocket, the film is fed over a curved gate and around a spring-loaded, pivoted tension roller to a drive sprocket, which is geared to the control sprocket. By taking different positions for various film shrinkages, the tension roller in effect measures the average pitch of the perforations in the length of film between the two sprockets. While doing this, it automatically controls the location of the film on the teeth of the control sprocket by moving the independently mounted, base-circle drum of the sprocket to make the film ride high or low on the teeth. Thus, the pitch of the two or three teeth nearest the gate matches the pitch of the film very closely.

To serve another important function, the tension roller is linked to the objective also. It moves the front and rear elements of the lens in opposite directions by different amounts to change its focal length to suit the pitch of the film, meanwhile keeping the lens focused on the film.

In addition, the pivot of one of the links can be moved to either of two fixed positions so that the lens can be focused quickly on the front or back of the film to match the position of the emulsion.

For this projector, the 3-in. $f/1.6$ objective must cover $2\frac{1}{2}$ frames without vignetting, and it must have a curved field to compensate for the curvature of the gate. To minimize keystoning, the radius of the gate must be approximately equal to the focal length of the lens.

Figure 7 shows the projector mounted on a General Electric flying-spot scanner and combined with a photoelectric unit and a second projector. The optical and mechanical parts of the compensator and film drive require very high precision in the various manufacturing and assembling operations. For example, the mirrors and their controls are made and adjusted to limits of not a few thousandths of an inch but a few ten-thousandths. In addition, the mirrors

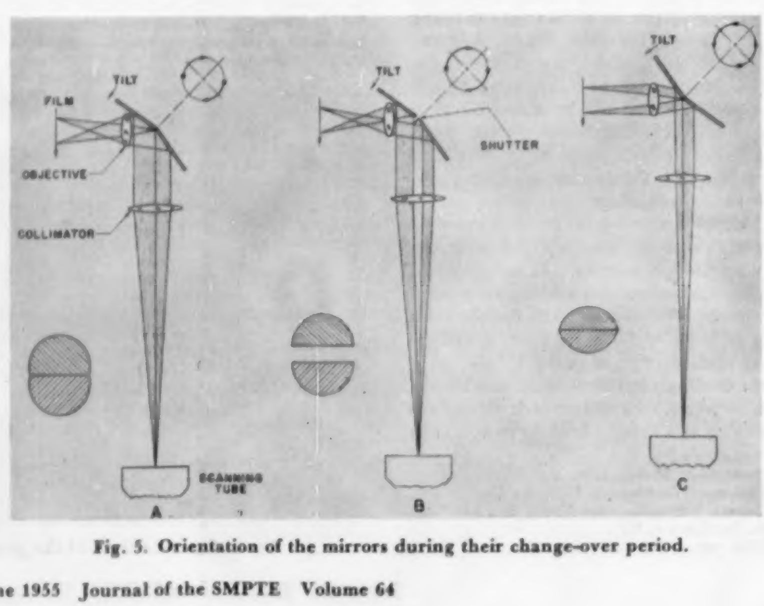


Fig. 5. Orientation of the mirrors during their change-over period.

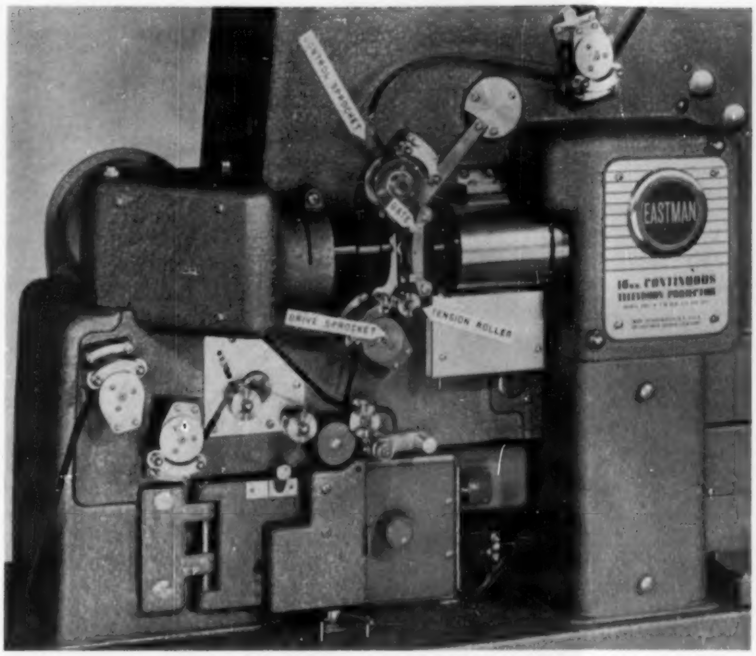


Fig. 6. Shrinkage-compensating mechanism.

must be optically flat, and they must be mounted and adjusted on their shafts so that their reflecting surfaces run true with respect to the bearings. It is necessary to grind the cam accurately and to adjust the pivots and ratios of the rocker arms to pair and match the mirror-tilting angles exactly to the focal length of the objective. Also, the control sprocket and the gearing between it and the camshaft require accurate construction.

Since the mechanism has ball or Oilite bearings, hardened sprockets and a hardened film gate, and sapphire edge

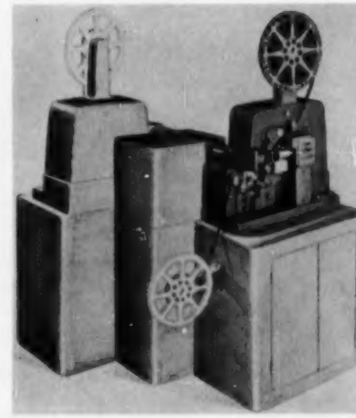


Fig. 7. Arrangement of the projector and its associated equipment.

guides for the film, it should give thousands of hours of service with little maintenance. An 1800-rpm synchronous motor drives the mechanism, synchronization being necessary for sound but not for image quality.

The soundhead, which is similar to that in the Eastman 16mm Projector Model 25, is shown in Fig. 6. It is driven by a small synchronous motor of its own. This motor is loosely coupled to the main driving motor to keep the two in phase during starting and stopping.

Without its 3000-ft reel arms, the projector is 26 in. long by 21 in. high by 11 in. wide.

Continuous-Projector Problems

By OTTO WITTEL
and DONALD G. HAEFELE

This paper outlines some of the problems encountered in obtaining satisfactory image steadiness in a continuous projector for television. The projector, which was described in a previous paper,* is of the type that uses rotating and tilting mirrors. Special attention is given here to the mechanical and optical refinements necessary for good performance, and to methods of analyzing and evaluating the results.

For some time, the Eastman Kodak Co. has been working on a continuous projector for television. At the 1954 spring meeting of the SMPTE in Washington, a descriptive paper* was presented on this projector, which is equipped with two rotating and tilting mirrors for optical compensation. It is the purpose of this paper to discuss some of the problems encountered in providing satisfactory image steadiness in a projector of this type.

Figure 1 of the earlier paper* shows a general view of the projector, which was designed specifically for use with flying-spot scanning equipment. Its main feature is an $f/1.6$ lens and the ability to handle the full $f/1.6$ cone of light. It was clear from the beginning that vertical steadiness would be the greatest problem. Past experience with TV projection had indicated that if the projector is to be of good professional quality, it should not introduce a frame-to-frame jump in the image greater than 0.0005 in. Three elements can contribute materially to this figure, the optical compensator, the film-transporting mechanism and the lens.

Figure 2 of the earlier paper* shows the optical system, including the collimator focused on the scanning tube, the compensating mirror at 45°, and the objective focused on the film. Actually, there are two compensating mirrors, each being semicircular in shape. They are designed to rotate and tilt in such a manner that the image of the raster of the scanning tube is held constantly in register on each frame of film as it moves past the objective.

Figure 1 of this paper illustrates how the mirror is assembled after it has been cemented to its mirror holder. Four adjusting screws permit accurate placement of the reflecting surface in a plane normal to a centerline through the bearings. This work is done in an optical fixture that also checks the flatness of the mirror. As finally adjusted, the movement of the image is restricted to 0.0002

Presented on October 19, 1954, at the Society's Convention at Los Angeles, Calif., by Otto Wittel (who read the paper) and Donald G. Haefele, Camera Works, Eastman Kodak Co., 333 State St., Rochester 4, N.Y.
(This paper was received on March 7, 1955.)

* Otto Wittel, "A continuous projector for television," *the preceding paper in this issue of the Journal.*

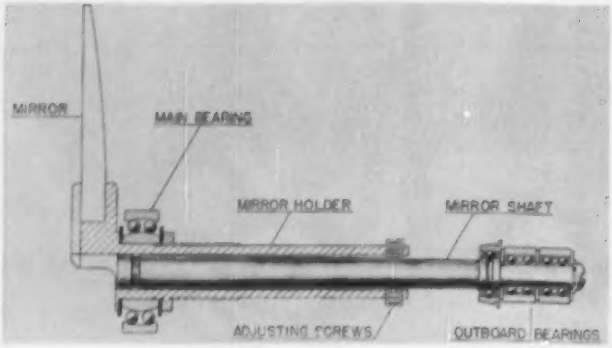


Fig. 1. Mirror assembly.

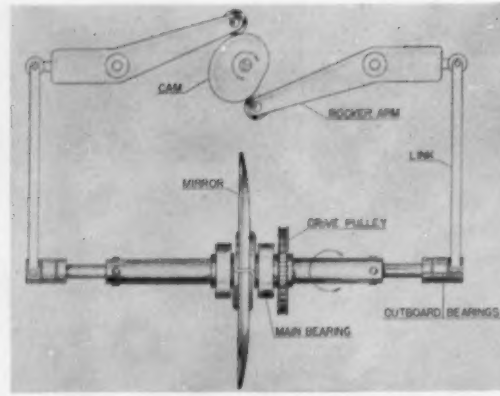


Fig. 2. Mirror-control linkage.

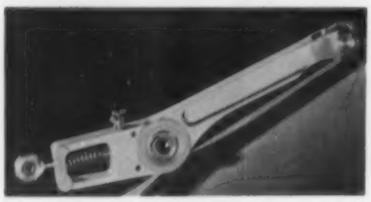


Fig. 3. One of the two rocker arms.

in. or less over the whole surface of each semicircular mirror. Because the mirrors rotate and tilt simultaneously, it was necessary to develop a special main bearing for this mirror assembly. Figure 1 reveals that both the inner and the outer race are spherical.

As outboard bearings at the other end of the mirror shaft, there are three separate ball bearings. The outer two are constructed so that the balls run directly on the shaft, and the inside bearing is a commercial product used merely to apply lateral spring pressure to the shaft. This pressure is to keep the center bearing against the rail on which it rides back and forth during the tilting action. Because this rail establishes the lateral steadiness of the image, it is adjustable.

As shown in Fig. 2 of this paper, each of the outside outboard bearings is connected by a link to a rocker arm actuated by a cam to tilt the mirrors. One mirror is rotated by a cog belt acting on the drive pulley, and the other is carried along by a flexible universal link between the mirrors. Because each mirror is out of balance, it was necessary to counterbalance the centrifugal force by means of two springs, shaped like horseshoes, that hold the two halves together. For simplicity, the connecting link and springs were omitted from Fig. 2.

The cam, which is the heart of this mirror-tilting mechanism, is hardened and ground, and it is made from a master four times as large as the finished part. On the controlling side, the rise of its surface is uniform, with a correction for the circular path in which the follower moves. For the return stroke, the motion is nearly harmonic, with some emphasis placed on keeping the acceleration low at the low point of the cam. An optical fixture was made to check these cams, and no errors greater than 0.0002 in. have been found.

Figure 3 shows one of the rocker arms. It is an aluminum casting, but the ratio of the length of the two arms can be adjusted by means of the eccentric control shown just to the left of the central bearing. In the main housing of the projector, there is also an eccentric adjustment for precise location of the center about which the arm rocks. The cam follower at the end of the arm is a commercial bearing of instrument quality.

Figure 4 is a sketch of the camshaft assembly. The shaft itself is hardened, ground and lapped. It is perfectly straight, without shoulders or recesses of any kind. Both the cam and the driving pinion are lapped to a wringing fit on this shaft. For each bearing, there is an assembly of 35 balls in direct contact with the shaft and arranged in a helical pattern, so that every ball has its own track. Their outer races are straight bushings hardened and lapped to a size that results in very slight preloading of the balls.

One very important problem was posed by the necessity of preventing play in the joints of the mirror-tilting linkage. It was necessary to design springs to control the play in the bearings over the life of the mechanism. Some of these devices are illustrated in Fig. 4 of the earlier paper.

Figure 6 of the earlier paper shows a view of the film path. Since the function of the optical compensator is to keep the image of the flying-spot raster superimposed on the moving frame or picture, the film-transporting mechanism was designed to move the film through the gate at a very uniform rate. Of variable pitch, the upper sprocket is the one that governs the motion of the film through the gate, and in Fig. 6, therefore, it is designated the control sprocket. From this sprocket, the film is drawn around the curved gate and a spring-loaded tension roller by a drive sprocket. Since the tension roller is pivoted to swing to the right or left, and there are 18 frames of film between the two sprockets, the posi-

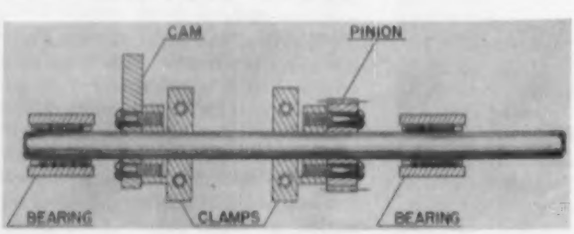


Fig. 4. Camshaft assembly.

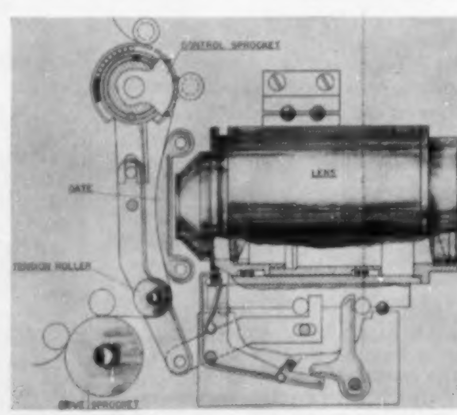


Fig. 5. Film path and shrinkage control.

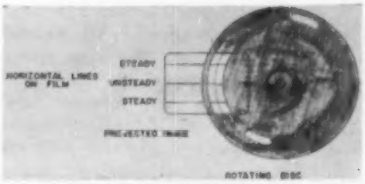


Fig. 6. Projection as seen through the analyzing disc.

tion of the roller is determined by the length of these 18 frames.

Figure 5 is a schematic view of the parts. This shows how the tension roller, which actually measures the shrinkage of the film, is linked back to the control sprocket to adjust the effective pitch of its teeth. It is linked also to the objective lens in such a way that it varies the focal length by a few per cent to suit the pitch of the film, while keeping the lens constantly in focus.

In the actual spacing of its corresponding surfaces, the teeth on the control sprocket do not vary more than 0.0001 in. However, the drum on which the film rides is supported by a ball bearing mounted on an arm that is free to swing on an eccentric pivot. Since this changes the height at which the film engages the teeth, it alters the effective pitch of the teeth. Eccentric adjustments provided at a number of the pivoted joints facilitate adjustment of the mechanism so that the pitch of the teeth nearest the gate is automatically established by the film to match its own particular shrinkage.

This variable controlling sprocket is driven from the camshaft through one simple gear reduction. Large, straight spur gears were used because it was felt that they could be made more accurately than gears of other types, and also to make sure that end play of the shafts would not affect the indexing of the teeth.

Of the major items to be considered in the design of the continuous projector, the third and last is the lens. It is a 3-in. $f/1.6$ lens of the modified Petzval type, and it was designed by W. E. Schade of the Eastman Kodak Co. Because it was necessary to use a curved gate to avoid keystoning, one requirement was to design a lens having a curvature of field closely approximating the cylindrical curve of the gate. Moreover, it was essential to have the lens cover $2\frac{1}{2}$ film frames without vignetting, which amounts to an angular coverage of 8°. Finally, and most important, there could be no distortion. It was stated above that a small adjustment of a few per cent in focal length is provided to compensate for various film shrinkages. This is done automatically and is controlled by the film itself, as shown in Figure 5. The lens mount was designed to roll on balls, with as little friction as possible.

After the projector had been assembled, it was found that certain testing devices were needed for the process of analyzing its steadiness. One reason for this was that with the flying-spot scanner, attention is drawn immediately to image movements of very short duration that are not visible in conventional projection. In fact, it appears that the scanning technique emphasizes this type of unsteadiness, which may occupy only a few lines. If the part of the image formed by these lines moves in relation to the rest of the image, the resulting "rubbery" effect is very obvious since only portions of an otherwise steady picture are moving.

One of the methods used to evaluate this short-interval unsteadiness is to make it visible with a special mechanism. This is shown in Fig. 6. Illumination is provided so that a chart film appears as a projected image on a ground glass, as indicated by the rectangular area in the illustration. Quite close to the ground glass is placed a rotating disk, which is driven by a special synchronous motor running at 1440 rpm.

This disk has two circular slots that are 180° apart and subtend 18° in length, but they are displaced radially so that the inner edge of one slot is in line with the outer edge of the other. With the disk covering part of the projected image, the motor can be shifted across the picture and rotated in its mount so that the slots can be positioned and timed to afford brief views, at half-frame intervals, of any part of the picture at any point in its transit through the gate. If there is any relative shift or unsteadiness between the two momentary viewings, it shows as a disjointing of the image of any horizontal lines or images on the film that cross the two slots. For example, the straight lines marked steady in Fig. 6 show that no such shift has occurred, while the disjointed line labelled unsteady indicates that the image moved during the half-frame interval between viewings.

In a second method of analyzing unsteadiness a 16mm motion-picture camera, without a lens, is mounted with its film in the plane normally occupied by the flying-spot scanner. With an illuminating system flooding the gate with light and the optics of the projector replacing the camera lens, a test film in the projector is imaged on the film in the camera. Because the image on the film in the camera is at right angles to that formed by the projector, vertical unsteadiness in the projector shows as horizontal movement on the camera film and thus is independent of the longitudinal steadiness of the camera. In this test, the camera is run slower or faster than the projector. In addition, the opening in the shutter of the camera is reduced to make the length of the exposure about 1/250 sec. The resulting film shows only one-eighth of the original frame, but the frame-to-frame unsteadiness is magnified eight times. In this manner, an analysis can be made of successive frames of the projected film, each being advanced or retarded, in its path through the gate, with respect to the preceding frame. This method results in a permanent record on film of the projector's performance.

The development of these special analyzing methods has led to a substantial improvement of the overall steadiness.

Flying-Spot Scanner for Color Television

By R. E. PUTMAN

A flying-spot scanner for use with a continuous-motion projector is described. Some of the problems that are encountered from the origination of the spot of light till the NTSC color output signal is obtained are discussed.

A FLYING-SPOT scanner system used in conjunction with a good continuous-motion projector offers a simple means of securing a good color-television signal. For years it has been felt that the use of a flying-spot scanner type of system offered great advantages for the transmission of film. Among these advantages were operating cost and simplicity of operation. With the advent of color another advantage was obvious — lack of registration problems.

The greatest need for such a system has been a continuous-motion projector. Such a projector has been designed by Otto Wittel and his associates at Eastman Kodak Co. and explained in detail in two papers.* General Electric, in close cooperation with Eastman Kodak Co., has designed a scanner system around this projector.

The projector is mounted on a base containing the flying-spot scanner tube, a 5AUP24 with an anode voltage of 27 kv obtained from a regulated kickback type of supply. Also contained within this base are the horizontal and vertical sweep circuits and a combination circuit for sweep protection and blanking. This protection circuit protects the scanner tube against the failure of either of the drive signals. Mounted on the projector is the audio preamplifier with an output of −10 dbm and in combination with the optical system of the soundhead, has an output of ±2 db from 50 to 6000 cycles.

An identical base is used for a dual 2 × 2 slide scanner where the light from the scanner tube is split by means of interference type filters for each 2 × 2 slide. The two slide holder disks hold a total of 16 slides and are remotely controlled.

By using a separate scanning tube for each projector the problems of keystoning and off-axis focusing are eliminated. The spot of light on the scanner tube is focused on the slide or on the film which has been immobilized in the projector, and is then treated simply as a bundle of light. A real image of the original spot is not formed again. This light is presented to photoelectric cells through a remotely controlled mirror change-over for selecting the projector desired, the necessary dichroics, and simple relay lenses to relay the cone of light in the objective lens to the photocells.

It is the dichroics that divide the light into its color components. Red information is taken off first, blue second and green is taken last. Although the dichroics tend to shape each spectrum into the correct taking characteristics, further shaping is required by filters in front of each photocell. To further assure the greatest utilization of the available light, interference type filters are used here with the resultant low insertion loss rather than gelatin-type filters. It should also be pointed out that the light passing over the surfaces of the dichroic beam splitters must be parallel. If this light is not parallel and has an angular variation along the surface of the dichroics color, shading will result. This is due to the fact that incident angular changes along the deposited surface of the beam splitters cause a change in the wavelength of light that is reflected or transmitted. Each photocell located in the pickup unit has its own preamplifier used for gain and impedance transformation. The outputs of these amplifiers feed the main amplifiers through a multi-conductor cable.

The main channel amplifiers are located in the rack, one for each color. Phosphor correction is the first function that is performed in this amplifier. This is necessary because the phosphor has a definite decay time. In fact, the scanning spot on the tube is best visualized as a spot with a tail, like a comet, moving across the face of the tube. The decay time can be matched by using CR and LR time constants in such a way that the tail of the spot is essentially eliminated.

The next operation performed in the amplifier is aperture correction. Aperture correction is simply a function to compensate for the size of the scanning spot on the tube. This has a finite size and as it tries to resolve finer and finer detail, it will be found that the finer the detail contained on the film, the lower the output voltage. In order to correct this deficiency, a high-frequency boost circuit with zero phase shift is added. This increases the amplitude of the signal for the higher frequencies, and thus improves the contrast for the fine details of the picture.

Because the picture tubes in color receivers, as in black-and-white receivers, do not have a linear relation between signal voltage and light output, but rather have a relation which approaches a true power law, the photographic term "gamma" has been generally used to specify this relation. It is standard practice to make all gamma corrections for the picture tubes at the studio, rather than in the receivers, thereby reducing the complexity and cost of the receivers. Consequently, "gamma" amplifiers are provided, the input-output characteristics of which are the inverse of those of the picture tubes. Each of the three color signals (R, G and B) is subjected to the same compensation in a separate but identical gamma correction amplifier. After gamma correction the signals are usually designated by the primed letters R', G' and B'. It is important to note that the rest of the transmissions system is assumed linear in amplitude, or that there is some means to make it so.

Blanking is also added along with minimum setup and a white clip circuit. The output of the channel amplifiers feeds an accessory unit known as a masking amplifier. There have been several papers presented concerning masking and its advantages when used with color film in a TV system.* Masking, a term taken from the photographic industry, means color correcting during the processing of color prints. The dyes used in color film do not have ideal spectral shape responses but each exhibit skirts which extend into the spectra occupied by the other dyes. These skirts that extend into the other dyes cause a desaturation of the color represented by that dye. The masking amplifier is a device that is used to compensate for these errors in the original dyes of the film by subtracting the proper amounts of unwanted colors from each of the main color signals.

The encoder receives separate red, green and blue signals from the three color channel amplifiers. From these the encoder forms "I," "Q" and "Y" signals as specified in the NTSC/FCC standard. I and Q are the "in phase" and "quad-

Presented on January 17, 1955, at the Society's Central Section Meeting at Chicago, by R. E. Putman, Electronics Div., General Electric Co., Electronics Park, Syracuse, N.Y.
(This paper was received on April 1, 1955.)

* See the two preceding papers in this issue of the *Journal*.

* W. L. Brewer, J. H. Ladd and J. E. Pinney, "Brightness modification proposals for television color film," *Proc. IRE, 42:* 174–191, Jan. 1954.

R. P. Burr, "The use of electronic masking in color television," *Proc. IRE, 42:* 192–200, Jan. 1954.

rature" video signals, respectively, which modulate the 3.58-mc color subcarrier in both amplitude and phase. Y is the "luminance" or brightness component of the complete color signal. It is the component which is displayed on black-and-white receivers. The modulated subcarrier, or "chrominance" signal and the Y or "luminance" signal are combined with sync and color burst to form the composite NTSC color signal. The encoder includes the circuitry necessary to key in the "color burst" mentioned above by generating within itself a proper "burst flag" or burst keying pulse, from the synchronizing signal alone.

The encoder also employs several original designs in its circuitry which make it easy to set up and operate. One of the adjustments necessary is the adjustment of quadrature phase. I and Q have to maintain a 90° relationship to each other. This means that the second harmonics have a 180° relationship to each other. Consequently, by amplifying the second harmonic, it is possible to adjust quadrature phase very accurately by adjusting for a minimum of the second harmonic signal. Amplified automatic gain control for the subcarrier has been incorporated assuring that the balance modulators receive a constant amplitude of 3.58 mc.

Another unique feature is the automatic 9-line key out. During the twice line frequency pulse in a vertical interval, no subcarrier or burst should be present. Also there is a definite relationship of the burst to the back porch as well as a definite width. One approach is to use "H" drive with a delay and width multivibrator and "V" drive for another width multivibrator. General Electric came up with a unique way of doing this automatically from sync. By using delay lines, it is possible to develop an automatic key out during the nine lines as well as the correct width for the burst located on the back porch. Contained in the output of the encoder is the feedback output stage giving 2 outputs capable of 1.4 v, peak to peak. The differential phase of this unit is in the order of 0.1% and the differential gain is in the order of 0.05 db.

The monitor switcher is also provided for looking at the individual colors on the black-and-white monitor and observing commutated colors on a wave form monitor. Final observation of the outgoing picture is presented on a color monitor.

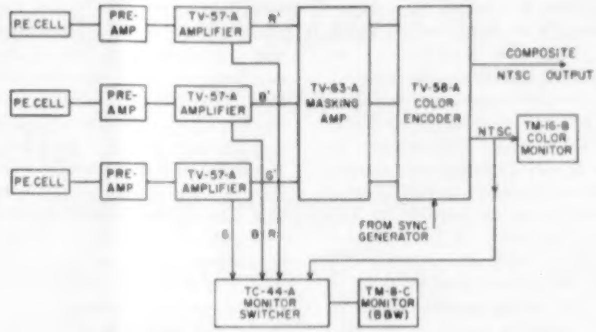


Fig. 1. Flying-spot scanner channel.

Thanks are due to the many people in the General Electric organization who contributed to the electronic portion of this project and to Mr. Wittel and his associates at Eastman Kodak Co. for the projector.

Television Studio Lighting Committee Report

By H. M. GURIN, *Committee Chairman*

One of the first problems which faced this committee was that of a common language which could be understood and accepted by all participants in television nomenclature. After considerable discussion, an initial listing of ten items was compiled and circulated to over four hundred interested parties. The resulting replies from approximately 20% of those approached, indicated overwhelming approval (90%) with some minor changes which were later included. The final versions of the lighting definitions have since been listed in the February 1955 *Journal*. This effort is a beginning and encouraging enough to warrant the continuance of this phase of the lighting committee's activity. Suggestions for additional terminology are not only welcome but are actively solicited.

A further objective of this committee is the standardization of instrumentation and measuring techniques. The question of the proper standards for meters both for incident illumination and for brightness measurements remains to be resolved. While the solutions to the problems for black-and-white television have not yet been provided, it appears to this committee that a tangible contribution could be made if the needs for color television were included in this study. Some early steps were taken to select a suitable pick-up angle for incident light measurements as well as to indicate a suitable spectral response for the photosensitive cell but these recommendations have not yet been formalized. Brightness meters have also been discussed but there was insufficient interest to continue this phase. However, there appears to be some concern for the control of brightness range in a television scene, particularly for color, warranting a complete review for future needs. It is hoped that vigorous studies will be undertaken in that direction. The increasing interest in color has also stimulated the need for color temperature meters and since there has been a wide variety of such devices for many years, the committee feels it is worth while to clarify and classify the special requirements for television. We are here looking for considerable help from the experience of our colleagues in the motion-picture and photographic industries. Along with the study of meters, techniques and procedures in using these instruments need unification. This item rates highly on the committee's agenda.

Another subject which merits further investigation is that of establishing practical but simple methods of determining the performance of lighting fixtures both as to the photometric characteristics and directional characteristics. Repeated requests by operating personnel of television studios have indicated the need for a simplified version of the classic procedures geared to the particular patterns of the television camera. Preliminary steps have been taken to utilize the experience of manufacturers and others to arrive at some mutually satisfactory result. It was therefore decided to invite the Illuminating Engeering Society to work jointly on this project and a subcommittee from the IES and the SMPTE respectively have initiated the

Presented on April 20, 1955, at the Society's Convention at Chicago by H. M. Gurin, National Broadcasting Co., 30 Rockefeller Plaza, New York 20.
(This report was submitted on May 2, 1955.)

necessary action. It is hoped that eventually fittings such as plugs, sockets, lamp sizes, etc., may be included in an extended program of standardization.

It soon became apparent that the scope had become so enlarged over that expected when the Committee on Television Studio Lighting was formed that it became necessary to call upon as many participants as possible if any practical results were to be achieved. It was therefore proposed that the TV Studio Lighting Committee increase its membership by setting up subcommittees in regional areas to carry out parallel programs with the main committee which heretofor had its principal activities concentrated in New York. Action was initiated to establish one section in Chicago under the leadership of William Rockar of WGN and a second group in Los Angeles under the direction of Howard Bell of Mole-Richardson Co. Both of these groups are being organized and are expected to produce tangible evidence of their efforts which can be combined with those from the East. If this plan succeeds, additional regional committees will be organized in areas where the interest and activity in television studio lighting warrant it. Another advantage gained from this consolidation of information will be the opportunity for participation and benefits to the smaller television station which had to depend largely, up to now, on the networks for major contributions.

The success of this ambitious venture depends entirely on the spirit of cooperation dictated by the recognition of the advantages to be gained, the support of all television stations, large and small, and the active assistance of the SMPTE membership.

news and reports

The Fall Convention at Lake Placid

Plans are snowballing despite the onset of summer. There will be a solid technical convention from Monday morning through Friday of the first week of October when the beautiful early autumn will be with us in the Adirondacks at the Lake Placid Club, October 3–7.

Following the Convention's theme, *Color in Motion Pictures and Television*, the Convention will be generally organized under:

Materials and Their Uses
Studio Practice
Laboratory Practice
Projection and Viewing
Television Practice
High-Speed Photography

A special chairman is working on each of these categories, as described in last month's *Journal*. Author's forms are available from the undersigned or from The Editor at Society headquarters. The deadline for titles and abstracts is August 1. Let us know promptly about any paper you believe should be in this program.

From Don Hyndman, Local Arrangements Chairman for the Lake Placid Convention, we have news about the special arrangements for SMPTE members and guests at the Lake Placid Club at Convention time. Accommodations are in the main hotel or in a large number of cottages which have a living room and two or more bedrooms. Rates are all American Plan (meals included) in either hotel or cottages: $18 a day for singles and $32 for doubles, with the living rooms $15 additional. Tipping is not allowed but 15% is added to your bill as a service charge.

For reservations, for the week, or for extra days before or after the Convention, write

Mr. Donald Nelson
Lake Placid Club
Essex County
N. Y.

Entertainment will be informal dress but substantial in available activities, as described in the National News Section of the Section Meeting Notices for June. We shall give you the tentative schedule of sessions in the next *Journal*.—*Glenn E. Matthews*, Program Chairman, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y.

Board Meeting

The second meeting of the Board of Governors for 1955 was held at The Drake in Chicago on April 17, the Sunday prior to the convention. John W. Servies, Financial Vice-President, reported that the Society's financial picture for the first quarter of 1955 was good, and all indications were that it would continue to be so.

Norwood Simmons, Editorial Vice-President gave an informative report of publications activities and emphasized the following point: that the new *Journal* format had, in general, been accepted favorably. There were complaints from librarians, however, that the *Journal* does not have a masthead and that minus its cover it lacks ready identification. For this reason, Mr. Simmons reported, a suitable masthead is being designed by the Editor and will appear first in the July issue.

Barton Kreuzer, Executive Vice-President, noted that the Executive Committee had authorized certain increases in *Journal* budget through the balance of 1955 which would permit an increase from 39 to 44 editorial pages each month.

In addition, Mr. Simmons urged that the budget be increased for the second half of the year to allow prompt publication of the 145-page backlog of manuscript material that had accumulated prior to completion of the 77th Convention Program.

Finally, Mr. Simmons explained that he and the Editor were considering publication in 1956 of a 40-year index to the *Journal*.

Axel Jensen, Engineering Vice-President, reported that standards work has been moving effectively as was evidenced by standards and progress reports which appear regularly in the *Journal*. Major emphasis, he stated, is now being given to the review of all standards that are five or more years old.

Future convention commitments were reviewed by Byron Roudabush, Convention Vice-President. In addition to those which appear on the inside back cover of the *Journal*, Mr. Roudabush offered for Board consideration the dates May 3 through 8, 1959, at The Fontainbleau, Miami Beach.

At the suggestion of E. S. Seeley, Secretary, the Board gave a great deal of attention to certain inconsistencies and deficiencies in the Bylaws and decided upon five amendments to the document, one of which would formalize the existence of the Executive Committee.

Because of the increasing amount of activity which falls into the province of the Sections Coordinator the Board discussed a proposal to create a new office of "Sections Vice-President." Since this would require an amendment to the Constitution, the Board decided that a detailed proposal, including exact wording of the amendment, should be prepared and submitted for approval at the July 1955 Board meeting.

The Board also approved a plan to form a Publications Advisory Committee whose

function would be to recommend to the Board long-range publications policy intended to insure a maximum of adequate service to the majority of the Society's members. The committee would provide a mechanism for the regular review of policy as motion pictures and television progress technically, and as the interests of members change.

President John G. Frayne submitted a detailed report on the first meeting of the Society's Education Committee, which was held in Hollywood on April 5. There were present 19 of the 28 committee members who represent labor, education, motion-picture studios and labs and TV stations. There was extensive discussion on training college students for positions in studios and labs and providing on-the-job training for those already employed. As a result of this meeting the group agreed to concentrate its activities on three main assignments: making an inventory of jobs that might be available for the next ten years; establishing short courses or institutes to meet current problems in the industry; and establishing a long-range training program. In addition the President indicated that he had appointed six committees to study educational training in such areas as film laboratories, studios, sound, cinematography and television.

John W. DuVall, National Membership Chairman, reported that he now had 71 members serving actively on the Membership Committee and that as a result he expected an abrupt increase in membership growth within the next 30 days. There was considerable discussion on the membership question and cautioning by the Board in this period of concentrated membership promotion to maintain a high professional standing among the membership. To insure that the real objectives of the Society are not lost sight of, Dr. Frayne appointed a six-man committee to review the Society's membership requirements, the practices followed by the membership committee, and the policies being observed in the matter of admissions. The members of this committee are: Frank N. Gillette, Chairman, Herbert Barnett, John W. DuVall, Charles W. Seager, Geo. W. Colburn and Charles W. Handley.

A suggestion was also made by Dr. Gillette that it would be wise to inquire of all delinquents why they had not continued their memberships.

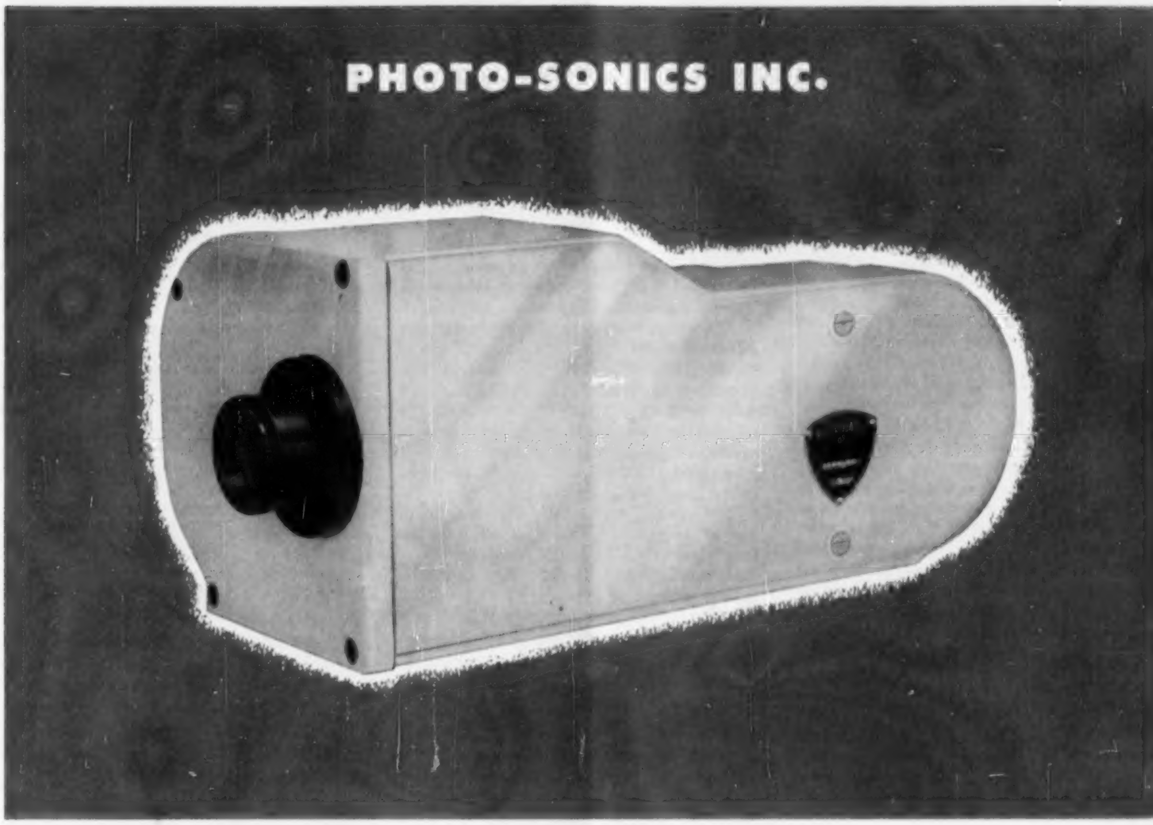
Before adjourning the Board set its next meeting date for Thursday, July 28, in New York City.—*S.G.*

International Standardization Meeting

The second meeting of Technical Committee 36 on Cinematography of the International Standardization Organization is being held in Stockholm, June 11 to 16. To be attended by more than 40 delegates from Belgium, Czechoslovakia, France, Germany, Italy, Mexico, the Netherlands, Sweden, the United Kingdom and the United States, its purpose will be to promote greater interchangeability of film among the nations by the establishment of international agreements on standards. At the first of these meetings, which took place in New York in 1952 and was reported in the October *Journal* of that year, considerable progress was made in this direction.

The United States delegation, headed by Dr. Deane R. White, Director of Research of du Pont's Photo Products Department, will consist of C. Adlerstrahle, Westrex Scandinavia; Axel G. Jensen, Bell Telephone Laboratories; W. F. Kelley, Motion Picture Research Council; J. W. McNair, American Standards Association; Marion E. Russell, Eastman Kodak Co.; Allen Stimson, General Electric Co.; Malcolm G. Townsley, Bell & Howell Co.; and Boyce Nemec, the Society's Executive Secretary, who will act as secretary for TC36. Axel G. Jensen, the Society's Engineering Vice-President, will be chairman of the meeting.

The U.S. delegation will offer eight American Standards and proposed standards on cinematography as possible items for the meeting's agenda. These include dimensions for 35mm motion-picture film; alternate standards for either positive or negative raw stock; dimensions for 8mm motion-picture film; dimensions for 35mm motion-picture short-pitch negative film; cutting and perforating dimensions for 35mm motion-picture negative raw stock; dimensions for 200-mil magnetic sound-tracks on 35mm and 17½mm motion-picture film; dimensions for 100-mil magnetic coating on single-perforated 16mm motion-picture film; magnetic coating of 16mm magnetic-photographic sound record; and 4-track magnetic sound for 35mm film.



35MM-2A RECORDING CAMERA

Designed Especially for High Camera Accelerations

This camera records high speed action on standard 35MM film with an aperture size of .370 x .875 inches. It is engineered primarily for use wherever high camera accelerations are to be encountered.

The rate of 200 frames per second is attained in one second by the 24 Volt DC drive motor After power is cut, the camera will stop within two seconds.

A dual pulldown arm, intermittent type movement is used. Register pins hold the film motionless during exposure cycle. The camera is operable in any mounting orientation.

The film capacity is 100 feet on daylight loading spools, which allows a running time of 16 seconds at 200 frames per second. Built-in features include buckle and run-out switches.

The complete unit is 6″ wide x 12¾″ long x 5¾″ high, weighs less than 20 lbs. Mounting stability is assured by four ⅜″–16 tapped inserts distributed over the large base. A centrally located insert makes provision for tripod mounting.

Timing is accomplished by two NE-51 neon lamps which are positioned on each side of the aperture and indicate the shutter position relative to the time base.

A boresighting and focusing viewer, glass lens shield, film footage counter and carrying case, for transporting and storing the instruments, comprise the optional and accessory equipment.

ADDITIONAL INFORMATION
ON REQUEST

PHOTO-SONICS INCORPORATED

2704 West Olive Avenue, Burbank, California

engineering activities

Interesting and challenging problems were the order of the day for the engineering committees which met during the Society's 77th Convention in Chicago during the week of April 18, 1955. Drafts of standards covering various aspects of the new look in motion pictures, instructions to the U.S. delegation to the June 1955 Stockholm meeting of ISO/TC 36, review of standards over five years old to bring them up to date, test films for color television and for magnetic sound, these among others were the vital issues with which the committees were concerned and which attracted a record attendance to these meetings. The resulting discussions were, for the most part, lively and fruitful. The essence of these discussions is presented below.

Color Committee

The activities of the four existing subcommittees were reviewed and a new subcommittee was formed to study the questions relating to the standardization of the measurement of the density of color sound-tracks.

Film Dimensions

American Standards Z22.71-1950 and Z22.72-1950 were reviewed and action was begun to revise these two standards. Processing of a draft standard for the dimensions of film for CinemaScope prints was continued and plans were made to draft standards for 16mm short-pitch film.

Film-Projection Practice

Revision of Z22.4-1941, the 35mm projection reel standard, was approved for letter ballot to the full committee. Three proposed aperture standards for: (1) CinemaScope With 4-Track Magnetic Sound, (2) CinemaScope With Photographic Sound and (3) Superscope With Photographic Sound were reviewed and improvements made in the accompanying appendix. Aperture (1) above was supported by the committee for international standardization. A detailed report on film cooling in projectors was presented by William Hecht, Chairman of the subcommittee on this subject, and plans were made to continue the study of this important question.

Laboratory Practice

The question of a uniform nomenclature is of commercial significance to the film-processing laboratories and extensive plans were made at this meeting to revise and bring up to date the existing standard, Z22.56-1947. Continued efforts were reported to establish a uniform method of cuing the printer light-change device which would eliminate the antiquated and destructive notching technique.

Screen Brightness

Proposed American Standard, PH22.100, Screen Brightness of 16mm Laboratory Review Rooms, was published for trial and comment in the January 1955 *Journal*. No adverse comments were reported and the committee supported further processing of this standard.

Dr. Armin Hill, chairman of the Subcommittee on Projection Screens, submitted an encouraging report indicating that progress was being made toward the Subcommittee's objectives of establishing the terminology, photometry and standardization of projection screens.

The screen brightness of drive-in theaters has been under active survey and a report on the data of 26 drive-in theaters was presented by Dr. Fred Kolb to the group. After making certain modifications, the committee approved the report for presentation to the Convention as a committee document. This will be published in an early issue of the *Journal*.

The international standardization of screen brightness is important for the international exchange of motion pictures and especially so with the advent of wide-screen processes. Much time was spent establishing the position the U.S. is to take on this at the forthcoming international meeting of ISO/TC 36.

16 & 8mm Committee

This meeting was almost completely concerned with standards in one form or another. Three standards sent to the committee with a letter ballot prior to the meeting were considered first. Of these three, one, Ph22.41, Photographic Sound Record on 16mm Prints, was approved for submittal to the Standards Committee. The second, SMPTE 824, Film Spools for 8mm Motion-Picture Cameras, was also approved but the closing of the letter ballot was left to the discretion of the chairman upon reaching the closing date. Several comments had been received on the third proposal, SMPTE 823, 8mm Motion-Picture Projection Reels. Agreement was reached to modify this first draft and a second draft is to be circulated to the committee shortly.

The requirement that American Standards be reviewed every five years led to an examination of four 1950 standards: Z22.19, Location and Size of Picture Aperture of 8mm Motion-Picture Cameras; Z22.20, Location and Size of Picture Aperture of 8mm Motion-Picture Projectors; Z22.80 and Z22.81, Scanning-Beam Uniformity Test Film for 16mm Motion-Picture Sound Reproducers (Laboratory and Service Types). There was agreement that all four standards should be revised. The substance of the revisions required in the first two was established and drafts of these proposals will be submitted to the committee with a letter ballot. The last two standards did not lend themselves to such rapid decisions regarding the nature of the revisions and a subcommittee was therefore formed to make the required study and to prepare the draft revisions.

The similarity of technical considerations between Z22.19 and Proposed American Standard, PH22.7, Aperature for 16mm Motion-Picture Cameras, led to the conclusion that certain aspects of the latter should also be revised. Accordingly, a new draft of this proposal will be prepared and submitted for committee consideration.

In addition, a brief period was devoted to certain test film considerations and to special size reels of 600-ft and 4000-ft film capacity.

Sound

Most of the work of this committee is presently going forward very nicely through correspondence. The meeting itself was therefore a brief one with the emphasis placed on bringing everyone up to date on the status of the three outstanding letter ballots and assigning responsibilities to one or two members for resolving the few questions that have been raised. The three proposals in question are: (1) PH22.40, Photographic Sound Record on 35mm Prints, (2) PH22.51, Intermodulation Tests, 16mm Variable-Density Photographic Sound, and (3) SMPTE 819, 4-Track Magnetic Sound for 35mm Film. The latter proposal was endorsed for international consideration.

Magnetic Recording Subcommittee

The dimensional aspects of magnetic striping and of magnetic sound-tracks were previously the most important areas of committee activity. At this meeting, the emphasis was shifted to magnetic test films. 16mm multifrequency, azimuth, flutter and signal level films and the specific questions relating to their production and standardization dominated the discussion. Of greatest significance is the agreement reached on the recording characteristics of the multifrequency test film and the reproduce characteristics of the projectors. This will permit the Society to proceed with production of the multifrequency test film and establishes the necessary foundation for the exchange of film with magnetic sound recorded on one projector and played back on another. It is intended to process the specifications for the reproduce characteristics as an SMPTE Recommended Practice. Plans were made for the further development of the other test films.

With respect to international standardization, it was agreed that the reproduce characteristic just approved should be used by the U.S. delegation as an indication of the present direction of U.S. industry on this question.

SMPTE Standards Committee and ASA Sectional Committee PH22

A joint meeting of these two committees was held to consider the agenda of the June 1955 meeting in Stockholm of the International Standards Organization Technical Committee 36 on Cinematography (ISO/TC 36). The U.S. delegation consists of nine people and the meeting was devoted to establishing the position this delegation should take on the various agenda items. In addition, a determination was made as to which documents should be circulated abroad as expressive of the U.S. position.

A report on the conclusions of this second meeting of ISO/TC 36 will be published in an early issue of the *Journal* just as soon as this material is available.

Television

Although the committee discussed 4000-ft reels, kinescope recordings and masking and gamma amplifiers, of major interest to those present was the question of a test film and test slides for color television. The contents of the ten 2 × 2 slides, 16mm and 35mm films which the Society expects to make available in the near future were described and the 35mm portion of the test reel to be supplied by Eastman, Ansco and Technicolor was demonstrated. The quality of this portion of the test reel was received with considerable enthusiasm. Announcement of the availability of this test material is expected shortly.

Television Studio Lighting

The committee reviewed the purpose and scope of the three projects under active consideration and the organizational structure of the two regional subcommittees whose activities will also revolve about these three projects which are: (1) equipment and performance ratings, (2) instrumentation and measurement and (3) nomenclature. These projects are described in greater detail in a committee report published elsewhere in this *Journal*.

Plans were made to have a Television Studio Lighting Symposium during the 79th Convention, April 29 – May 4, 1956, in New York City which will include papers on the lighting requirements for both color and monochrome television broadcasting.—*Henry Kogel*, Staff Engineer.

Posthumous Honor for Frank C. Gilbert

The memory of Frank C. Gilbert, chief engineer of Altec Service Corp., has been honored by the U.S. Navy Underwater Sound Laboratories, New London, Conn., through the dedication of Franklin C. Gilbert Road, principal thoroughfare on Fort Trumbull Reservation.

The ceremonies, conducted by Capt. Edward J. Fahy, U.S. Navy Commanding Officer and Director, included the unveiling of a plaque by Gilbert's widow. The commemoration took the form of a tribute to the supreme sacrifice made by the Altec chief engineer in action during the submarine campaign waged by Germany off the New Jersey coast during World War II.

On leave of absence from his company at the time, Gilbert, in company with E. S. Sealey, present Altec chief engineer, T. H. Carpenter, and other Altec technicians, was engaged in anti-submarine warfare research and development in behalf of apparatus for the detection and destruction of submarine raiders. His death came in a blimp while testing experimental detection gear off the Jersey coast.

Education, Industry News

The National Association of Photographic Manufacturers, Inc., has announced that it is cooperating with the State University of New York in establishing a new two-year course for high school graduates in Photographic Equipment Technology.

Designed to equip the student to earn a good living in the photographic technical field and to live as an effective citizen in his community, the course has been established at the Long Island Agricultural and Technical Institute at Farmingdale, N.Y., and will begin at the opening of the regular fall term. First year subjects to be taken in three quarters will include General Education, Mathematics, Physics, Mechanical Drafting, Electricity, Construction and Maintenance, Photographic Techniques, Electronics, Machine Tool Laboratory, Photographic Mechanics, Accounting and Physical Education. All these courses will be slanted to show the application and use of the information provided in the photographic service field.

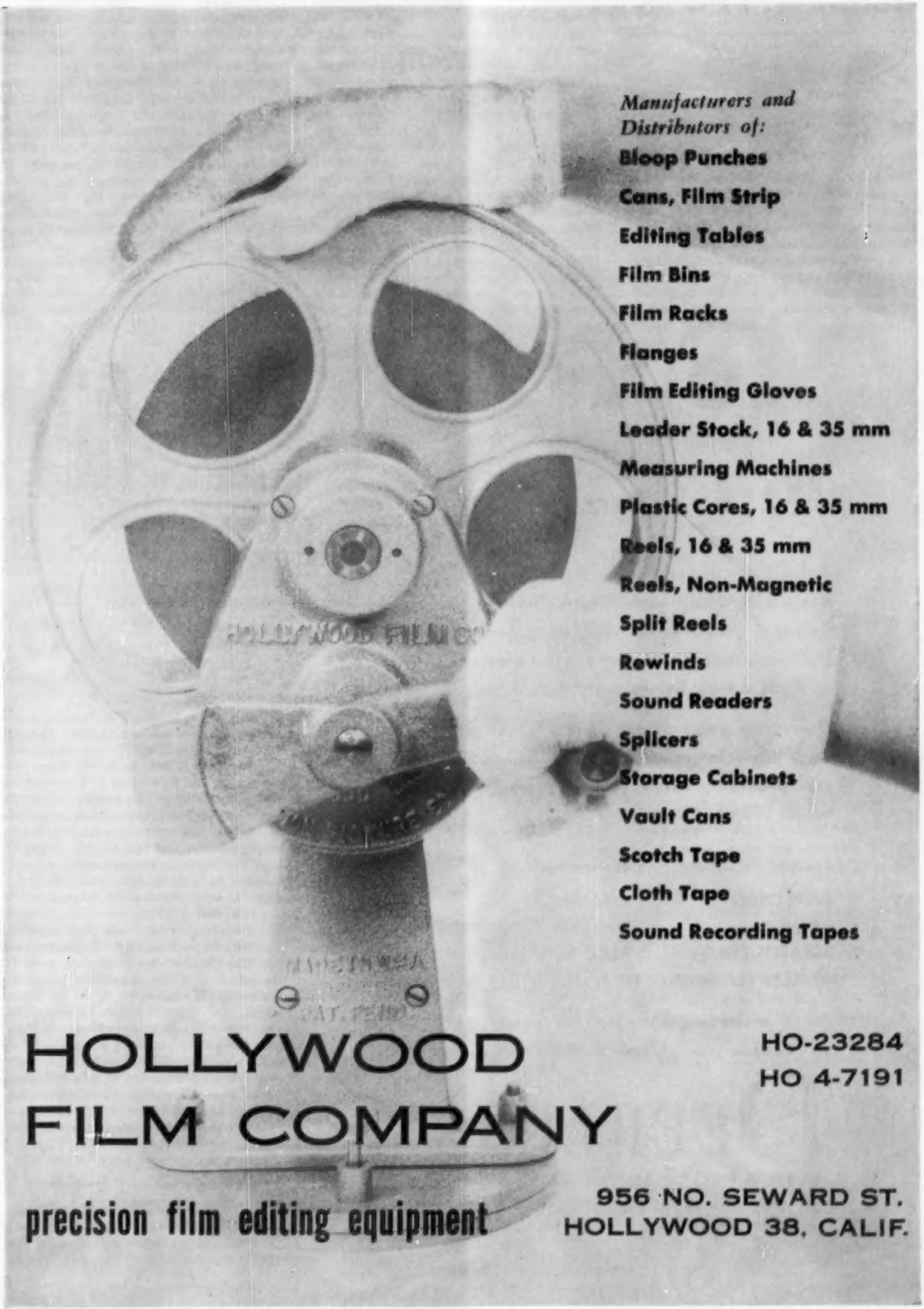
The second year of study offers courses in the Modern Community, Business Organization and Management, Photographic Techniques, Electronics, Instruments, Applied Psychology, Photographic Materials, Electronics Shop, Inventory Control Techniques, and Physical Education.

Applicants for the courses must be 16 years or older and must be graduates of approved four-year high schools (or hold equivalent diplomas). The two-year program will lead to the college degree of Associate in Applied Science. Tuition will be free to residents of the State of New York. Full information may be obtained from: Office of Admissions, Long Island Agricultural and Technical Institute, Farmingdale, Long Island, N.Y.

Rochester Institute of Technology has announced a seven-week midsummer course in "Fundamentals of Color Processing and Photography," under the direction of C. B. Neblette, head of the Department of Photography. The first half of the course, which begins July 11, will have particular application for motion-picture lab people, since it will deal with the basic fundamentals of color photography and processing involving chemical controls for processing film. Lectures will be delivered by faculty members of RIT and outstanding technicians and executives from the Eastman Kodak Co. and Ansco. Technical demonstrations are also scheduled during the course.

Bell & Howell Co. recently announced five new executive appointments in the optical and professional equipment divisions. George L. Oakley, formerly manager of professional and industrial sales, has been appointed manager of the company's professional equipment division. Mechanical engineering of professional equipment will be headed by Arthur C. Mueller, who was formerly head of the camera design department. Warren Delhorbe will be responsible for the electronics design of professional equipment. Everett F. Wagner has been named manager of the optical division, and Arthur Cox has been appointed optical director to head up the optical design and tooling departments and do liaison work in optical market development and quality control.

In addition, Bell & Howell has sent Arthur H. Bolt to be its new vice-president of western operations at the company's Hollywood offices.


Manufacturers and
Distributors of:
Bloop Punches
Cans, Film Strip
Editing Tables
Film Bins
Film Racks
Flanges
Film Editing Gloves
Leader Stock, 16 & 35 mm
Measuring Machines
Plastic Cores, 16 & 35 mm
Reels, 16 & 35 mm
Reels, Non-Magnetic
Split Reels
Rewinds
Sound Readers
Splicers
Storage Cabinets
Vault Cans
Scotch Tape
Cloth Tape
Sound Recording Tapes
HOLLYWOOD
FILM COMPANY
HO-23284
HO 4-7191
precision film editing equipment
956 NO. SEWARD ST.
HOLLYWOOD 38, CALIF.

section reports

The Atlantic Coast Section held its fourth program meeting of the calendar year on April 27. The program, in the Moderne Roome of the Belmont-Plaza Hotel, consisted of a symposium on magnetic editing. The panel members were: Col. Richard Ranger of Rangertone Inc.; Stanley Russell of George Blake Enterprises; Richard Mack of Langlois Filmusic; James Townsend of Unifilms, Inc.; Mauro Zambuto of Italian Film Enterprises; Alan Wolf of Westrex, Hollywood; and Moderator Burton Perry of Westrex, New York.

Each of these gentlemen, representing some aspect of magnetic sound recording and editing, delivered a brief talk about his connection with the use of magnetic tape or film and the manner in which he approached the editing problem. Following the prepared part of the program, the audience asked questions and engaged in discussions with the panel members. It appears that splicing, maintaining sync and exact spotting of key words or sounds were the matters of chief interest. Richard Mack presented an example of addition of music to an old silent cartoon. The music came from a magnetic library and was edited to be effectively in sync with the cartoon action. This emphasized his point that magnetic editing could be both precise and feasible with respect to cost and time.

Attendance approached a total of 200 members and guests, with some of the section members coming from as far as Ottawa, Canada; Providence, R.I.; and Schenectady, N.Y. Prior to the meeting, approximately 50 members and guests dined together at the Belmont-Plaza. This was the first endeavor in this direction in many years for the Atlantic Coast Section. It was the consensus of opinion of those present that the section should plan its programs for future meetings to include an occasional down to earth "How To Do It" type of meeting such as this.—*George Gordon*, Secretary-Treasurer, c/o Eastman Kodak Co., 342 Madison Ave., New York 17.

books reviewed

Mathematics in Type

Published (1954) by the William Byrd Press, 1407 Sherwood Ave., Richmond, Va. i–xii + 58 pp. 6 × 9¼ in. Paper covered. Price $3.00, with 50% discount to educational Institution staff members.

The mission of this difficult little book is more than to expose the abilities and attitudes of The William Byrd Press; it is to bring practical education to those who teach and lead by writing in mathematical language. Study of this treatise will create a basic ability with mathematical symbols, economical habits and an understanding of why mathematical language is printed as it is. The organization and text of this little volume are concise and most efficient in order to cover thoroughly: Factors Affecting Difficulty of Composition; Methods of Composition; Setting and Spacing; The Eccentricities of Letters; Preparing and Marking Manuscript (including such information as a list of symbols frequently confused); Variables of Style in Manuscript, in Type; Proof Changes and Corrections; Kinds and Sizes of Type; List of Symbols. An apt quotation in the book is one from Alfred North Whitehead—"By relieving the brain of all unnecessary work, a good notation sets it free to concentrate on more advanced problems, and in effect increases the mental power of the human race."—*V.A.*

The 1955 Film Daily Year Book of Motion Pictures

Published (1955) by the Film Daily, 1501 Broadway, New York 36. 6 × 9 in. 1264 pp. incl. adv.

This well-known trade handbook has reached its 37th year, and its accumulation

of information by now makes a weighty package. From general essays on the progress of the industry down to the most detailed statistics and actual information there is practically nothing to do with the organization of the motion-picture business that cannot be found somewhere in this volume. Names, addresses, film titles, industry statistics of all kinds are all here. Especially noteworthy is the increasing amount of information about the television networks, including detailed personnel listings of television stations.

A few copies of the Year Book are available at $10, but it is available free of charge to subscribers to The Film Daily. Subscriptions, which cost $15 per year within the U.S. and $20 per year abroad, entitle the subscriber to 5 copies of the Film Daily, issued five days a week, in addition to the Year Book.—*D.C*

Of Publishing Scientific Papers

By George E. Burch. Published (1954) by Grune & Stratton, 381 Fourth Ave., New York 16. 40 pp. 8 × 10 in. Paper covered. Price $2.75.

The author who is Henderson Professor of Medicine at Tulane University School of Medicine has in 30 paragraphs done a neat clinical job. Originally an address, it is now published in attractive form with cartoon illustrations which by their simplicity and bluntness may belie the incisiveness of the text. Beginning with the "investigator author" who is further faceted as sometimes a self-plagiarist, self-aggrandizer, etc., the book finishes with the "lay press," the cartoon displaying the printer arriving with a fresh report titled "Kidneys Make Urine," to the obvious satisfaction of the "sensationalist" author. Although very rewarding, this essay seems over-priced.—*V.A.*

The Proceedings of the Symposium on Modern Network Synthesis conducted by the Polytechnic Institute of Brooklyn April 13–15, 1955, will be published in book form in October 1955 as Volume V of this series of Proceedings. Areas covered include network design methods, time domain synthesis and active networks. Price of the book will be $5.00 and orders should be addressed to: Polytechnic Institute of Brooklyn, Microwave Research Inst., 55 Johnson St., Brooklyn 1, N.Y.

A List of American Standards — 1955 edition — has just been published by the American Standards Assn., 70 E. 45 St., New York 17. The publication has an index to about 1500 American Standards. There are 210 for construction and civil engineering; 153 mechanical standards; 272 electrical; 62 metallurgy; 69 chemical; 165 textiles and wearing apparel; 158 safety; 251 photography and motion pictures; 74 petroleum products; 10 office equipment and supplies; 32 letter symbols, drawings and abbreviations; 38 gas-burning appliances; 18 mining; 11 rubber; and a miscellany of other. A separate *section on consumer* contains an index of standards for household appliances, wearing apparel, hobby cameras, etc.

Developments in Large-Screen Closed-Circuit Television

[A report presented on April 20, 1955, at the Society's Convention at Chicago]

Closed-circuit television, now averaging one telecast per week, is growing into a major communications medium. Bringing special information, entertainment and sports to selected audiences, closed-circuit TV is contributing a positive television service wholly different from broadcasting. Sometimes known as the private life of television, closed-circuit TV is a powerful force in reaching selected audiences with drama and impact.

Little known a few years ago, it is estimated that more than four million persons have viewed closed-circuit TV in the last few years, and that the public has spent more than five million dollars to see theater television.

Company sponsors have spent over six million dollars in closed-circuit TV business meetings. This corporate use of a relatively new medium suggests an important future for it.

I am proud that our company,

Theatre Network Television, Inc. — known to the trade as TNT — has presented 90% of all large-screen, closed-circuit TV and that during this coming month it will present its 82nd large screen, closed-circuit telecast. A record of 71 theaters was established for the closed-circuit telecast of the second Marciano-Charles heavyweight championship fight last September, 1954, and we expect to exceed that figure for the coming Marciano-Cockell championship fight on May 16. For the General Motors telecast commemorating the manufacture of its fifty millionth car last November, we established a record high of 52 hotels and auditoriums — the biggest mobile projection network ever organized.

Early closed-circuit TV featured big theater events such as championship prize fights, football, basketball and baseball games and outstanding entertainment attractions such as the Metropolitan Opera. Although some of these important sports and entertainment attractions have continued, they have not yet achieved more than a sporadic schedule. The expansion of this pay-as-you-see closed-circuit function necessarily awaits the next growth cycle of big-screen projection installations in theaters — which may be nearer than many suspect.

Closed-circuit TV for business meetings

The General Precision Laboratory Model PB-610 projection equipment, with high-voltage supply at right.

— what we call Tele-Sessions — offers an important continent-spanning communications system. Transporting corporate management and information rapidly across the electronic network, it saves time and money and brings company communications directly to many who otherwise would be left out.

These business meetings have given rise to an entirely new concept of television distribution, resulting in national mobile networks. Since meeting places vary according to the client — hotels, theaters, auditoriums or plants — and since the cities for each client are different, we have developed a mobile network which goes where the client wants. This differs fundamentally from the structure of broadcasting networks whose station affiliates are in permanent locations. Necessarily, the development of a mobile Tele-Sessions network has brought new engineering problems.

The first problem was proper big-screen, black-and-white projection equipment. There are 112 big theater-type projection equipments, including a few intermediate film systems permanently installed in theaters located in about fifty cities, coast to coast. This was the backbone of the early development of Tele-Sessions and was utilized to inaugurate the idea of closed-circuit TV business meetings. In 1952, when Lees Carpets became the first company to utilize large screen, closed-circuit TV, they reached into 17 cities coast to coast, and theaters constituted the basic network. Since then such companies as Dodge, Ford, Chrysler, National Dairy, Frankford Distillers and others have used theaters. Even then, it has been common to supplement the theater cities by installing temporary mobile projection equipment in hotels and auditoriums.

The theater network, convenient and available, gave birth to Tele-Sessions. But as the medium began to grow, it became apparent that the small size of many company audiences and the necessity in some cases for afternoon and evening meeting hours required other appropriate meeting places such as hotels.

The first nationwide hotel network was launched late in 1954, when General Precision Laboratory completed manufacture and delivery to TNT of the first quality projection equipments especially designed for hotels. These equipments were designed for ruggedness, mobility and quality. They consist of two parts: A control rack measuring 5 × 2 × 2 ft, with the projector barrel seated on top and capable of appropriate tilting, and a high voltage supply. These combined parts weigh 570 lb and are rendered easily mobile by their rollers. Accompanying this equipment is a portable screen and a sound unit for use where the hotel has none of its own.

This General Precision unit, labelled model PB-610, was built to use up to forty thousand volts and for easy plug-in to the electrical supply in any auditorium. Utilizing the Schmidt optics system, this projector has achieved excellent quality pictures ranging from 7 × 9 ft to 9 × 12 ft in most of the work to date. It may be capable of even larger picture size with acceptable results. In some 300 hr of program performance in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EST. 1926

General Motors President Harlow H. Curtice photographed as he appeared on TNT large-screen, closed-circuit TV, in one of the 52 cites of a coast-to-coast Tele-Session.

TNT closed-circuits, there has not been a single failure in part or whole.

In addition, a large number of large theater-size General Precision projectors, Model PB-600, were rendered mobile for special use to larger audiences. The development of the new quality equipment and the supplement of mobile, large theater-size units have expanded the abilities of closed-circuit TV so that it is possible to offer the type of facilities and services important customers expect. Additional new projection equipment is now being built by other manufacturing concerns which too may meet quality closed-circuit standards.

The delivery of our new projection equipment posed problems of servicing and operating in the field. Every closed-circuit telecast, excluding permanent theater installations, is, in a sense, like going on location — with all the problems involved in operating in a new and strange place each time. On each separate occasion in each city there is problem of shipping the equipment to the designated meeting place, its reception, its check out, the connection of the equipment to the power supply, its firing up, the positioning of the screen and the projection equipment to accommodate the size of the audience, the survey of the audio system in meeting places which often have none, and ultimately, of course, the connection of the projection system to the telephone loop which, in turn, connects into the interexchange channels of A.T.&T. back to the point of origination.

Major national service companies have begun to develop experienced personnel capable of practical handling of such situations, so that each nationwide closed-circuit telecast now has a national army of servicemen who perform the field maneuvers required. The RCA Service Co. and TNT entered into the first national service contract in closed-circuit TV last fall, and this method of field service has been so successful that others have followed.

Having established itself, closed-circuit TV is now at a point where novelty and experimentation can no longer carry the day. More and more, closed-circuit TV is being judged by its performance on a practical and regular basis. Accordingly, the establishment of quality standards has become a necessity in the closed-circuit TV industry. It will be quality performance and service which will enable closed-circuit TV to continue its great growth and it is in this direction that the engineers and technicians have an important role to perform.

I recommend that this Society undertake the role of guide to closed-circuit TV and that it address itself to helping this young industry establish proper standards.

Unfortunately, some recent arrivals in closed-circuit TV are operating on an agency concept of leasing inferior equipment and without background or experience themselves, they are not contributing to the medium. Closed-circuit TV, no less than broadcast TV, requires know-how, judgment and experience — and a dedication to quality performance. The closed-circuit medium will become stabilized as a regular TV service when the network concepts of complete facilities and service become its guiding standards. To this end, TNT has organized the first owned and operated national network in closed-circuit TV by distributing its large screen TV projectors in 41 major cities. They are available for closed-circuit TV at all times. We believe that this network organization will lead to the continuous

development and increase of quality standards.

We have learned throughout the years that it takes effective integration of TV production, long line transmissions, loop connections and large screen projection to achieve the quality pictures and sound required in this medium. The lowering of standards in any one of these TV pipe lines deteriorates the program.

It has become necessary for closed-circuit TV companies to develop special production techniques in the studio or on remote location. The lighting standards for large screen TV are different, for example, from broadcast practice, with much greater intensity and a tendency toward flat lighting. A monumental task was performed in re-lighting the entire stage of the Metropolitan Opera House last November when its opening night was televised closed-circuit coast to coast. 350,000 watts were brought in by TNT to light the great stage at the Metropolitan Opera House, compared with home TV requirements of about 35,000 watts for a big musical studio production. This perhaps illustrates some of the difference in lighting.

The sensitivity of matching cameras is much greater for large-screen TV. Although in the early days special grey scales were devised for matching cameras to be used for our theater TV productions, we found such tests inadequate. Beginning in 1953, we instituted the procedure of matching cameras by monitoring on large-screen projectors, rather than relying on the small control room pictures.

The skillful use of certain kinds of camera shots, with emphasis on the close-up and tight lenses, has developed as a standard practice for large-screen productions. Since most camera crews are broadcast trained, it has become necessary to develop sufficient experienced large-screen supervisory personnel to guide the camera crews in appropriate telecasting for big-screen TV.

With practice over the years, the telephone system has achieved better results in transmitting the originating signal. It is well known, however, that certain sections of the telephone system, particularly those involving the use of coaxial cable, do not produce generally as good transmission results for large-screen as the microwave links.

There are still restrictive results for large-screen signals when transmitted through the narrow 4-mc passageways of the long-lines telephone system. And there remain definite bottlenecks in clearance and service for closed-circuit by the telephone companies, although this area is improving.

Primarily a growth situation itself, closed-circuit TV must continue to grow technologically too. The first commercially designed black-and-white large-screen projection equipment of seven years ago should be up-dated in every theater. Both the manufacturer and theater operator are responsible.

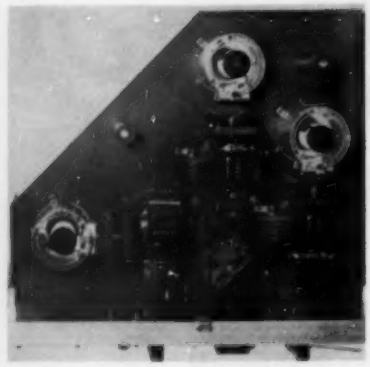
With the increase in motion-picture size, some theater men believe that the theater TV picture should be larger too, particularly for comparable entertainment attractions. This can and should be accomplished. More recently designed optics systems permit the projection of the world's largest TV pictures. Among some of our mobile equipments are projectors which have exhibited TV pictures in drive-in theaters of 47 × 65 ft, with sufficient clarity and light for audience enjoyment.

As color TV progresses, large-screen color projectors are expected. Some of the pioneering work in this field has produced fabulous prospects for further growth of large screen TV.

But the bright future of technological and business growth in closed-circuit TV should not be dimmed by inferior quality performance today. So I end with a plea for the establishment of and adherence to quality standards for the closed-circuit TV industry.—*Nathan L. Halpern*, Theatre Network Television, Inc., 575 Madison Ave., New York 22.

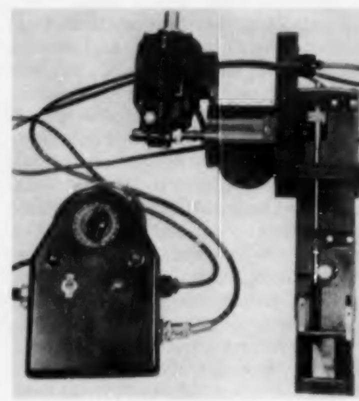
new products
(and developments)

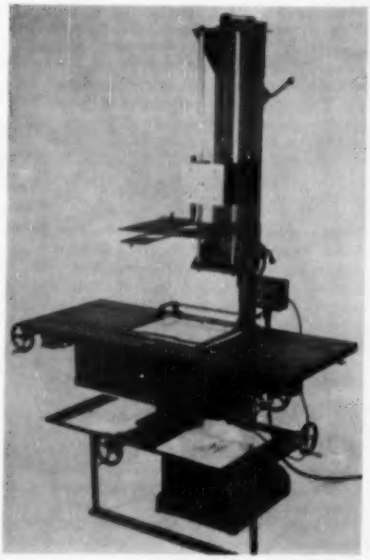
Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products or services.



A three-light, color-compensating head for use in printing color motion-picture film has been designed and marketed by Fish-Schurman Corp., 70 Portman Rd., New Rochelle, N.Y. Shown is the head for use on a Depue reduction printing machine. Heads have also been developed for the Model D Bell & Howell continuous printer. In front of each light there is a condensing system with a stack of five neutral density filters, solenoid-operated. These three lights with their stacks of filters are brought toward a set of dichroic beam splitters and are merged into a single aperture. In front of each stack of filters there is a solid-colored glass filter which serves as a trimmer. The equipment can also be used for superimposing work. Printing rates of up to 100 ft/min of color positive stock are reported, and the firm advises that plans are for equipment to deliver at double that speed. The overall size of the head is 22$\frac{1}{16}$ by 27$\frac{1}{2}$ by 21$\frac{3}{4}$ in.

An automatic fade attachment for use with Model "JA" and "DA" Bell & Howell Continuous Contact Printers is being made by the Motion Picture Printing Equipment Co., 8136 North Lawndale Ave., Skokie, Ill. The new fade attachment is made expresly for the 300-w super-high intensity printer lamphouse, and can be inserted into the lamphouse in place of the filter holder. A filter holder pack is supplied. In the fade attachment the shutter blades are driven by a mechanical clutch which is connected to a variable-speed motor whereby the fade lengths can be varied. Fades of from 20 to 160 frames can be obtained. The mechanical clutch is operated with a breaker box which operates from a standard film notch placed in the negative on the soundtrack side. An indicator light unit shows when the shutter blades are opened and closed. Price of the attachment, for either Model "JA" or "DA," is $695.00 f.o.b. the manufacturer's plant.

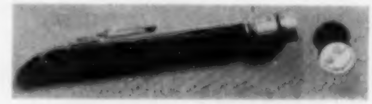




The Tel-Animastand is an equipment of modest lines first displayed in the Exhibits at the SMPTE Convention at Chicago in April. Also demonstrated there was the accessory equipment called the Tel-Animaprint Hot Press Title Machine shown below. These have been introduced by S.O.S. Cinema Supply Corp., 602 W. 52 St., New York 19.

Standard features of the animation stand are the movable, counter-balanced, vertical carriage for the camera; the table which turns a full 360° while moving in any direction; Acme Peg Bar registration system; a manually operated zoom assembly adaptable to motorized movement; a field of operation of 4 to 12 in. wide; a quick-reference rule set in 1/20-in. increments; an adjustable platen to hold flat artwork of varying thicknesses; a pantagraph for plotting camera movements; an art table which takes art up to 18 in. by 24 in.; four Veeder-Root counters; and shadow board with built-in matte device and shadow box for backlighting.

The Tel-Animaprint has an Acme Peg Bar Lineboard and pegs system for registration. Foundry type is handset in a 9-in. typeholder (a stick to printers), and impressed upon color foils to produce titles, etc., which are dry and can be handled immediately.



Fredzlite is a 3-color "safe" pocket flashlight for photographic purposes, having a turret adaptable to all standard pocket flashlights. The three openings in the turret are supplied red, green and amber but any color filter can be used. The complete item, illustrated, is available at $4.75 from Metlen Mfg. Co., P.O. Box 2186, Seattle 22, Wash.

A new manual covering the technical aspects of the various products used in the photographic lighting field has been issued and made available to the public at a price of $2.00, obtainable from Dept. JO, Sylvania Electric Products Inc., 1740 Broadway, New York 19. There is a section on projection lamps illustrating base construction, bulb type and ventilating procedures. The 16-page section on the Sylvania concentrated arclamp may be of special interest. The manual is in loose-leaf form in a substantial binder holding the $5\frac{1}{2} \times 8\frac{1}{2}$ in. pages.

employment service

These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

TV/Motion-Picture Coordination. Registered professional consulting engineer with unique combination experience in TV/film and live production, broad administrative and demonstrated technical ability, can bring technical knowledge and production experience to bear on commercial film production and do shirt-sleeve work. Experience includes executive TV work in major agency, writing and producing commercials, and national networks. Author of 3 books and scores of articles; TV consultant to universities; also professor teaching *all* phases TV and TV films; able to get along with people; well-known in industry, speaker, active in industry committees, NTSC, Senior Member IRE, SMPTE. Age 39. Write: c/o Hewitt, 4315 Saul Rd., Kensington, Md.

16mm Cameraman. 15 yr experience; age 41. Last 7 yr as head cinematographer in medical college shooting color exclusively; editing and some animation, also all-round still and lab work, black-and-white and color. Seeking permanent position; complete résumé from: Robert A. Leonard, 2100 10th Ave. South, Birmingham 5, Ala.

Television Floor Manager. Young married man desires TV floor position with aggressive station. Recently completed film seminar at New School (New York). Show business background; acting, directing. Will locate anywhere. Write: Joseph R. Masefield, 15 Berkeley Place, Brooklyn 17, N.Y.

Film Recording Engineer: Age 33, 4-yr experience motion-picture film recording, adjustment, operation and maintenance of these equipments: optical film recording; sprocket-driven and ¼-in. magnetic recording; and of kine recording. Also: sound transmission measurements; film density tests; film laboratory liaison. Heavy electronic development laboratory background; former AAF Electronics Officer; desires New York City location but will travel—Daniel A. Thaler, 158-30 90th St., Queens 14, N.Y.

Positions Available

Audio Laboratory Engineering Assistant. Will set up, operate and maintain audio equipment in Audio Division of major consumer testing organization; will construct auxiliary equipment as required; will assist division head and others in testing audio equipment sold to public. Required—degree in electrical engineering or equivalent experience; also 3–4 yr experience in audio equipment operation and maintenance; some familiarity with theory and mathematics of audio electronics and acoustics. Salary $100 up depending on individual. Send résumé to Personnel Director, Consumer Reports, 17 Union Sq. West, New York 3.

The Signal Corps Pictorial Center at 35-11 35th Avenue, Long Island City 1, N.Y., has an immediate need for applicants meeting the U.S. Civil Service Commission requirements for two positions listed below:

Photographer (M.P. Timer), GS-9: $5060/yr, male. Applicants must have had at least 5 yr of progressively responsible experience in motion-picture photographic laboratory work of which 2 yr must have been spent in motion-picture timing. The applicant's experience must demonstrate a thorough knowledge of all phases of positive and negative developing theory and a knowledge of densities, exposures, photographic solutions and the physical properties of various types of film utilized.

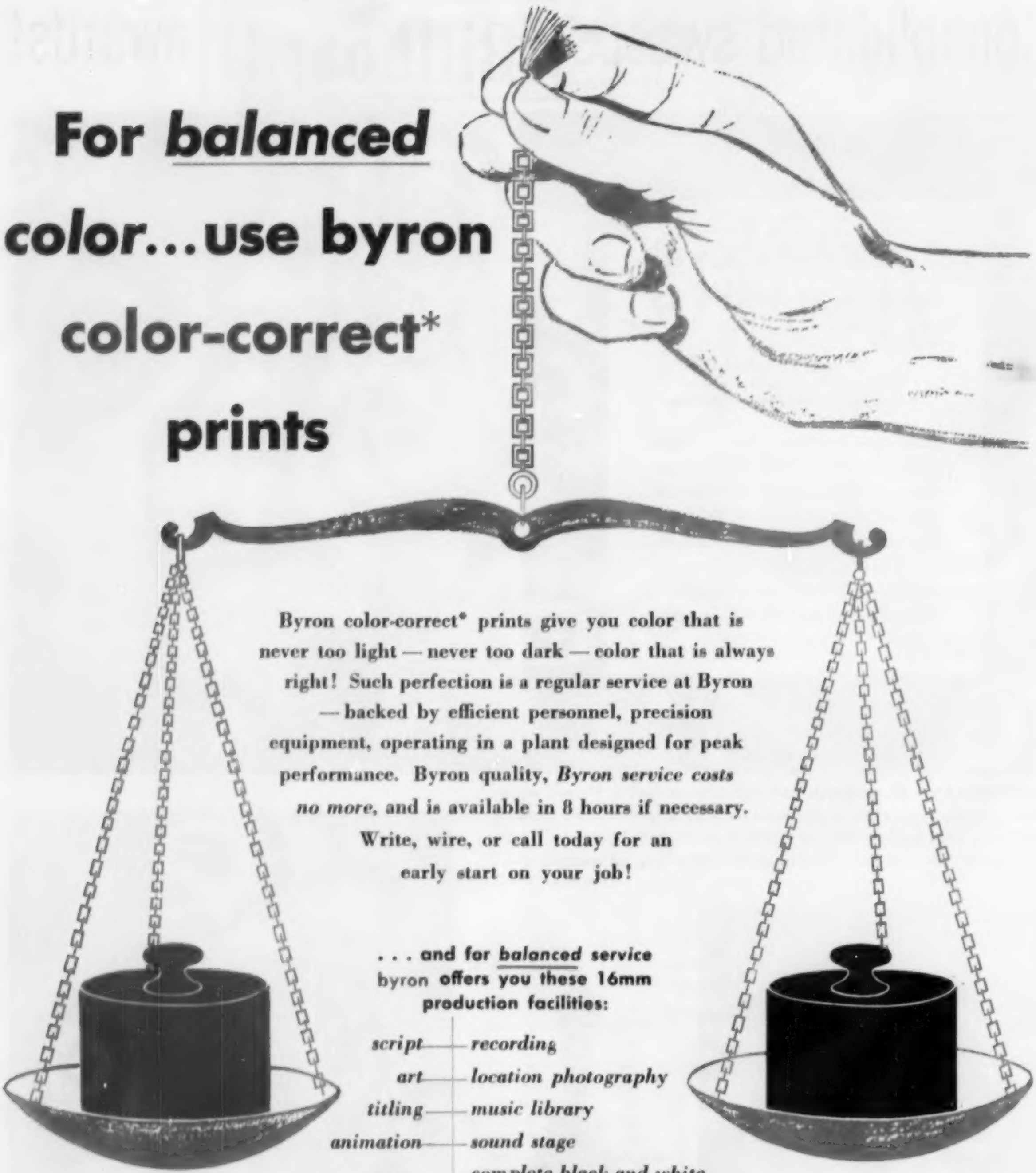
Photographer—Laboratory Technician (M.P. Color Sensitometrist): GS-7: $4205/yr, male. Applicants must have had 4 yr of experience in reading soundtrack and sensitometric strips by means of densitometers, including plotting, interpreting and recording data to evaluate factors involved such as gamma, speed, density and characteristics of printing machine, processing solutions and photographic emulsions.

B.S. or M.S. Physicist or Electrical Engineer with experience in photographic or magnetic sound recording. Will serve under Process Supervisor to investigate problems of photographic sound quality. Knowledge of film printing and processing equipment, recording methods, and film sensitometry desirable. Salary open. Send brief résumé incl. approx. salary requirements to E. E. Griffith, Technicolor Motion Picture Corp., 6311 Romaine St., Hollywood 38, Calif.

Film Inspectors: Permanent or summer positions open. Telephone or write — Mr. Kern Moyse or Miss Annabel Compton, Peerless Film Processing Corp., 165 W. 46 St., New York 36.

Require experienced 16mm motion picture laboratory technician for position as lab supervisor for growing motion-picture laboratory. Must be thoroughly experienced in control and processing color and B&W motion-picture films. Salary and percentage to man who can qualify. Send résumé and references to Western Cine Service, Inc., 114 E 8th Ave. Denver 3, Colo.

Professional Services



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Meeting Calendar

International Commission on Illumination, June 13–22, Zürich, Switzerland.
American Society of Mechanical Engineers, Semiannual Meeting, June 19–23, Hotel Statler, Boston, Mass.
American Rocket Society, Semiannual Meeting, June 19–23, Boston, Mass.
International Aeronautical Conference, joint mtg. of the British Aeronautical Society and the Institute of the Aeronautical Sciences, June 21–24, Los Angeles.
American Institute of Electrical Engineers, Summer General Meeting, June 27–July 1, New Ocean House, Swampscott, Mass.
Acoustical Society of America, June 30–July 2, Pennsylvania State College, State College, Pa.
National Audio-Visual Association, Convention and Trade Show, July 22–27, Hotel Sherman, Chicago
Biological Photographic Association, Annual Meeting, Aug. 30–Sept. 2, Wisconsin Hotel, Milwaukee.
American Chemical Society, National Meeting, Sept. 11–16, Minneapolis, Minn.
Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Hotel Statler, Cleveland, Ohio
Instrument Society of America, Sept. 12–16, Shrine Exposition Hall and Auditorium, Los Angeles.
National Electronics Conference, Oct. 3–5, Hotel Sherman, Chicago.
78th Semiannual Convention of the SMPTE, Oct. 3–7, Lake Placid Club, Essex County, N.Y.
American Institute of Electrical Engineers, Fall General Meeting, Oct. 3–7, Morrison Hotel, Chicago.
Photographic Society of America, Oct. 5–8, Sheraton-Plaza Hotel, Boston, Mass.
Optical Society of America, Oct. 6–8, Hotel Wm. Penn, Pittsburgh, Pa.
Audio Engineering Society, Oct. 12–16, Hotel New Yorker, New York.
American Standards Association, 37th Annual Meeting and Sixth Annual Conference on Standards, Oct. 24–26, Washington, D. C.
American Rocket Society, Nov. 13–18, Chicago.
American Society of Mechanical Engineers, National Meeting, Nov. 13–18, Hotels Congress, Hilton and Blackstone, Chicago.
American Institute of Chemical Engineers, Nov. 27–30, Hotel Statler, Detroit.
Acoustical Society of America, Dec. 15–17, Brown U., Providence, R. I.
79th Semiannual Convention of the SMPTE, Apr. 29–May 4, 1956, Hotel Statler, New York.
80th Semiannual Convention of the SMPTE, Oct. 7–12, 1956, Ambassador Hotel, Los Angeles.
81st Semiannual Convention of the SMPTE, Apr. 28–May 3, 1957, Shoreham Hotel, Washington, D.C.
82d Semiannual Convention of the SMPTE, Oct. 6–11, 1957, Hotel Statler, New York.

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SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April Journal.

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